

PB-214 886

JAMES RIVER-WILSON CREEK STUDY,
SPRINGFIELD, MISSOURI. VOLUME I

Robert S. Kerr Water Research Center
Ada, Oklahoma

June 1969

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 214 886

JAMES RIVER-WILSON CREEK STUDY
Springfield, Missouri

U. S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
South Central Region
Technical Services Program
Robert S. Kerr Water Research Center
Ada, Oklahoma

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

VOLUME INDEX

Volume I Main Report

Volume II Appendix A Physical and Chemical
Methods, Raw Data,
and Selected Monitor
Strip Chart Records

Appendix B Benthic Study

Appendix C Fish Investigation

Appendix D Groundwater Investigation

JAMES RIVER-WILSON CREEK STUDY
Springfield, Missouri

I

CONTENTS

	<u>Page</u>
INTRODUCTION	
Authority	1
Background	1
Objectives and Scope	2
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS	
Summary	4
Conclusions	6
Recommendations	9
HISTORY OF THE PROBLEM	16
DESCRIPTION OF THE PROJECT	
Location	25
Characteristics of the Area	26
Project Work Plan	27
DISCUSSION	
James River	30
Lower Wilson Creek Basin	34
Surface and Groundwater Relationship	34
Odor Problems	35
Springfield Southwest Sewage Treatment Plant	37

	<u>Page</u>
Upper Wilson Creek Basin	40
Jordan-Upper Wilson Creek	40
Fassnight Creek	44
North Wilson Creek	45
South Creek	47
Stormwater Runoff-Water Quality Relationships	47
Continuous Measurement of Streamflow and Quality	48
Storm Runoff from the Upper Wilson Creek Basin	50
Sewage Treatment Plant Bypasses	54
Scour of Sludge Deposits	55
ACKNOWLEDGMENT OF COOPERATING AGENCIES AND INDIVIDUALS	57
BIBLIOGRAPHY AND EXHIBIT	
Bibliography	59
Exhibit A	Following Page 60

LIST OF TABLES

		Following Page
Table 1	Description of Sampling Stations	28
Table 2	Overall Project Averages of the Various Physical and Chemical Parameters of Water Quality and Rates of Flow	38

LIST OF FIGURES

		Following Page
Figure 1	Location and Vicinity Map	(Back of Report)
Figure 2	Water Quality Monitor and Accessory Equipment	27
Figure 3	James River and Wilson Creek	30
Figure 4	Flow, Dissolved Oxygen, Temperature, pH, and Conductivity Profile of James River	30
Figure 5	Nitrate, Organic Nitrogen, Ammonia, and Phosphate Profile of James River	30
Figure 6	Benthic Organisms - James River	31
Figure 7	Number of Species of Fish - James River and Wilson Creek	32
Figure 8	Number of Game, Rough, and Forage Fish Caught per Hour - James River and Wilson Creek	33
Figure 9	Flow and Dissolved Oxygen Profile of Wilson Creek	34
Figure 10	Ammonia, Temperature, and pH Profile of Wilson Creek	34
Figure 11	Sewage Treatment Plant Efficiency	37
Figure 12	Benthic Organisms - Wilson Creek and Tributaries	39
Figure 13	Monitor Locations	48
Figure 14	Monitor Strip Chart Section - Station 27	49

INTRODUCTION

Authority

This study is authorized by Section 5(b) of the Federal Water Pollution Control Act, as amended, which states: "The Secretary may, upon request of any State water pollution control agency, or interstate agency, conduct investigations and research and make surveys concerning any specific problem of water pollution confronting any State, interstate agency, community, municipality, or industrial plant, with a view of recommending a solution of such problem."

In a letter dated October 4, 1966, to the Regional Director, South Central Region, Federal Water Pollution Control Administration, the Executive Secretary of the Missouri Water Pollution Board requested assistance in a pollution problem near Springfield, Missouri. A copy of the letter of request is included as Exhibit A.

Background

The pollution problem for which assistance was requested manifests itself in two ways:

1. Occasional fish kills, associated with storm runoff, in the James River and in Wilson Creek below Springfield; and
2. Odorous and unsightly conditions in Wilson Creek in the vicinity of Wilson's Creek Battlefield National Park.

The major fish kills of record occurred: the week of April 19, 1954; July 18, 1960; August 4, 1960; and July 16, 1966. In all of these cases, the rate of flow of the James River above its confluence with Wilson Creek was estimated to be less than 25 cfs, based on flow

recorded at gages located on the river just above Lake Springfield at Kinser Bridge and at Galena. Thunderstorms over the City of Springfield, located in the upper Wilson Creek basin, produced a rise in Wilson Creek not accompanied by a rise in the James River. This caused Wilson Creek to dominate flow at the point of confluence, possibly in a ratio as high as 40 to 1.

The Springfield area is underlain with limestone, severely complicating the water quality problems. Large quantities of surface water and significant volumes of waste water enter the upper groundwater aquifers through the numerous sinkholes and crevices in the area, some of which are in the bed of Wilson Creek. This water passes through a virtual maze of fractures and solution channels in the limestone and reappears as surface water further downstream, often in a degraded condition. Water has been observed flowing out of some of the sinkholes during periods of heavy runoff within the basin. This condition is due to runoff entering the higher sinkholes in excess of the hydraulic capacity of the underground flow system.

Objectives and Scope

In line with the foregoing background information and the many discussions among concerned agencies and individuals, project objectives were established as providing answers to the following:

1. Why do fish kills occasionally occur in Wilson Creek and the James River?
2. What is the source of pollutants causing the kills?
3. What steps can be taken to eliminate the pollution causing the kills?

4. Why do odors emanate from Wilson Creek?
5. What is the source of pollutants causing the odors?
6. What steps can be taken to eliminate the pollution causing the odors and unsightly conditions?

Planning activities required some six months, including various meetings and discussions, area reconnaissance, study and review of prior investigations, preliminary sampling and testing of area streams, preliminary flow studies, determination of methods of attack on the problems, working up time and cost estimates, setting up the project on CPM (Critical Path Method) for project management purposes and to aid in interim reporting, writing and reviewing the project proposal, and physically gearing up for the field work.

Field work on the project extended over an eight-month period.

Planning, field, and various support activities involved about 50 individuals from four Federal agencies, three State of Missouri agencies, the City of Springfield, and numerous private citizens.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

1. The assistance of the Federal Water Pollution Control Administration in the study of an unusual pollution problem at Springfield, Missouri, was requested by the Missouri Water Pollution Board in a letter dated October 4, 1966.
2. The pollution problem for which assistance was requested was believed to be related to surface runoff as well as treated sanitary and industrial wastes tributary to Wilson Creek, which in turn is tributary to the James River.
3. Manifestations of the problem are essentially two-fold:
(1) Occasional fish kills, associated with storm runoff, in the James River and Wilson Creek below Springfield; and (2) Odorous and unsightly conditions in Wilson Creek in the vicinity of Wilson's Creek Battlefield National Park.
4. All previous major fish kills of record occurred during periods of low flow in the James River, when thunderstorms over the City of Springfield located in the upper Wilson Creek basin produced a rise in Wilson Creek not accompanied by a rise in the James River.
5. Water quality problems are complicated by the cavernous limestone topography of the area. Large quantities of surface water and significant volumes of waste water enter the upper groundwater aquifers through numerous sinkholes, some of which are in the bed of Wilson Creek. This water reappears as surface water further

downstream, primarily at Rader Spring, often in a degraded condition.

6. Investigations have been made by various Federal, State, and local agencies following fish kills in the past. These investigations have revealed the polluted condition of Wilson Creek and, in general, the conditions under which fish kills occur. The surface and subsurface flow relationships have also been partially revealed. Although causes of the fish kills were not conclusively demonstrated, oxygen depletion was strongly implicated. Several possible causes of this were set forth. These included sewage treatment plant bypasses, scouring of sludge deposits, industrial waste discharges, storm runoff from Springfield, and slugs of poor quality subsurface water from Rader Spring entering surface waters.
7. A 1967 report by consulting engineers on the condition of the Springfield Southwest Sewage Treatment Plant indicates the plant is reaching its design capacity. It also pointed out that excessive flows received into the plant during rainy periods, at times causing bypass, were due both to infiltration and storm drain connections.
8. Following consideration of the extensive background information and discussions among concerned agencies and individuals, project objectives were established as listed on Page 11.
9. To fulfill project objectives, a work plan was developed to make the following investigations: (1) Measurement of physical and

chemical parameters; (2) biological studies; and (3) a groundwater study. The first category involved the continuous measurement of four parameters of water quality at four strategic locations and the measurement of a wide variety of water quality indicators at all important sampling stations during a dry period in July and again following general rains. The biological studies included a survey of bottom dwelling invertebrates in the area and an investigation of the fishery in the James River and Wilson Creek. The groundwater studies included geological mapping, geophysical surveys, groundwater quality studies, and groundwater tracing.

Conclusions

1. All physical, chemical, and biological data indicate that the James River is mildly degraded in quality, or biologically enriched, by the waters of Wilson Creek. Severe pollution does not exist in the river, except during brief periods of heavy storm runoff in the Wilson Creek basin during low flow conditions in the James River.
2. From visual appearances, Rader Spring was of better quality during the period of study than in times prior to the study. One reason for this change was the stoppage, or partial stoppage, of inflow to the crevices in the bed of Wilson Creek immediately below the discharge of the sewage treatment plant, thus reducing the ratio of sewage effluent to available dilution water in the underground water system. However, this stoppage cannot be considered permanent.

3. Basin-wide groundwater quality studies revealed no other significant sources of groundwater pollution other than that of Rader Spring which might affect the quality of Wilson Creek.
4. The lack of strong, septic odors in Wilson Creek during the study period largely negated the odor control objectives of the project. This absence of strong odors is attributed to the improvement of quality at Rader Spring.
5. Weak to mild sewage odors did at times exist in Wilson Creek below the sewage treatment plant. Rather extensive sludge deposits are in evidence; and rocks on the stream bottom are coated with heavy growths of blue-green algae, stimulated by the high concentration of ammonia discharged from the sewage treatment plant.
6. The Springfield Southwest Sewage Treatment Plant performs quite efficiently during normal operations in the removal of oxygen demanding materials. However, due to a lack of dilution, Wilson Creek is severely polluted below the discharge. Due to infiltration and stormwater connections to sanitary sewers, plant bypass occurs during and following moderate or heavy rains in the sewered area.
7. Both the chemical and biological data confirmed the marginal water quality in much of the Wilson Creek basin and the severely polluted condition of Wilson Creek below the sewage treatment plant.

8. The many and diversified industrial concerns in Springfield contribute heavily to the waste load coming into the Southwest Sewage Treatment Plant. Several industries, through discharge to surface waters, contribute to the generally degraded condition of surface waters in the Wilson Creek basin.
9. The James River fish kills have been caused by slugs of poor quality water, low in dissolved oxygen, moving down Wilson Creek on the leading edge of heavy storm runoff during low flow conditions in the river. The low and rapidly changing concentration of dissolved oxygen with respect to location is accompanied by high levels of ammonia and suspended solids and sudden changes in other parameters such as temperature, pH, and conductivity.
10. The primary sources of this poor quality water are:
 - A. Urban storm runoff from the upper Wilson Creek basin, specifically runoff from the downtown Springfield area, into Jordan Creek and runoff from the North Wilson Creek basin; and
 - B. Scouring of sludge deposits in the bed of Wilson Creek below the sewage treatment plant by the increased velocity and turbulence of storm runoff.
11. Bypasses from the sewage treatment plant, which generally enter Wilson Creek nearly simultaneously with the leading edge of storm runoff from the upper basin, further contribute to the poor quality water moving downstream. However, these bypasses are considered to be of secondary importance due to their

relatively small volume in comparison with the volume of the storm runoff. The bypasses of sewage alone are not of sufficient volume to cause a slug of low DO water in Wilson Creek of the magnitude measured by the monitor at the north edge of the national park.

12. In times prior to the study when Rader Spring was more severely polluted by secondary sewage effluent moving into the underground feeder streams, circumstances indicate that the poor quality storm runoff was still further deteriorated by large surges of septic water from Rader Spring and Rader Sink. The surges occur when increased hydrokinetic pressure in the underground flow system is created by runoff into inlets of the system at higher elevations.

Recommendations

Control of Storm Runoff

1. It is recommended that engineering studies be conducted to determine the most feasible and economical means of retarding the movement and reducing peak flows of stormwater runoff down Wilson Creek.
2. It is recommended that a broad-scale sanitary survey be conducted in the upper Wilson Creek basin, with emphasis on the downtown, industrial, and commercial areas, for the purpose of identifying existing conditions or practices which contribute to the poor quality of urban storm runoff. Remedial measures needed may

include intensified street sweeping during low-flow periods in area streams, occasional flushing of storm sewers, elimination of depressions or ditches where casual water or waste may collect or stagnate, and improved industrial waste disposal practices (covered in detail later). Without such remedial measures, urban runoff problems are certain to intensify as Springfield further develops.

Springfield Southwest Sewage Treatment Plant Improvements

1. It is recommended that the City of Springfield proceed with its plans to construct a polishing lagoon. This lagoon will be very beneficial for several reasons which include:
 - A. Elimination of sludge deposits in the bed of Wilson Creek. The deposits have been caused in part by solids carryover from the final clarifiers, and the pond will hydrolyze or settle out these solids.
 - B. Elimination of mechanical plant bypasses to Wilson Creek.
 - C. Elimination or reduction of unsightly growths of blue-green algae below the sewage treatment plant. Nitrification in the pond will reduce the ammonia content of the secondary effluent, thus depriving the blue-green algae of the necessary nutrients.
 - D. General improvement in the quality and appearance of Wilson Creek. Slight improvement may also be noticeable in the James River below Wilson Creek.

Consideration should be given to providing mechanical aeration

in the pond as an aid to pond oxygen assets, to achieve reduction of ammonia content, and to improve pond circulation. In the pond design and construction, it is imperative that the unique geological problems of the area be considered, as discussed in the Groundwater Investigation, Appendix D.

2. It is recommended that engineering studies be continued for the purpose of improving and enlarging mechanical plant facilities. In addition to the construction of additional aeration tanks, clarifiers, solids handling units, and other accessory equipment, post-chlorination should be provided to improve the aesthetic qualities of Wilson Creek. Such qualities will become increasingly important with the growth and development of Wilson's Creek Battlefield National Park. Advanced waste treatment techniques may become necessary in the future due to the lack of dilution in Wilson Creek, the continued growth of Springfield, and the increasing emphasis on recreation by the public. With a high level of water quality, Wilson Creek will become an asset to Springfield rather than a liability.
3. It is recommended that the City of Springfield accelerate their program of sanitary sewer inspection for the purpose of reducing or eliminating storm drain connections and sewer infiltration.

Industrial Wastes

1. It is recommended that improvements be made in the industrial waste treatment facilities of the Frisco Railroad. Stormwater runoff must be excluded from the treatment facilities. The

oil-water separator and holding pond are helpful and should be retained. However, the chemical precipitation procedure used in the small final pond is ineffectual and probably does more harm than good. Studies should be initiated to determine the suitability of the holding pond effluent for various forms of chemical or biological treatment, with the goal of improving the quality of the final effluent. Consideration should also be given to discharging the holding pond effluent to the sanitary sewer if the waste is acceptable for inclusion into the sanitary sewer system.

2. It is recommended that improved water pollution control procedures be initiated at the Hoffman-Taff Pharmaceutical Chemical Plant.

These include:

- A. Inspect and make necessary revisions to plant piping to insure that the cooling water discharges do not become contaminated with process chemicals or waste.
 - B. Collect and deposit into the process waste pond the small volumes of waste being discharged on the west side of the plant.
 - C. Protect from flood waters by retaining wall or other means the contents of the process waste holding pond.
 - D. Store and handle all hazardous chemicals in such a manner as to preclude their entry into Jordan-Wilson Creek by accidental spill or from being washed into the stream during periods of rainfall or flood.
3. It is recommended that improved industrial waste disposal practices be initiated at the MFA Plant Foods plant (fertilizer

manufacturer). Storm runoff from the premises must be excluded from the industrial waste system. Due to the small volume of waste, it appears feasible to enlarge the pond system and cease discharging to Jordan Creek.

4. It is recommended that Harker Paint Company cease the discharge of paint or paint ingredients to Jordan Creek. A trap, spill basin, or similar device is needed.
5. It is recommended that the reasons for past oil spills into Fassnacht Creek from Kraft Foods Company be investigated and that steps be taken to prevent recurrence of the spills. An oil trap on the storm sewer may be desirable.
6. It is recommended that floor drains in the Springday Rubber Company be removed from the storm sewer to South Creek and connected to the sanitary sewers.

Control of Groundwater Pollution

1. It is recommended that concerted efforts be made to restore Rader Spring to a high level of quality. Although recent improvements have taken place, additional improvement would produce great benefits to lower Wilson Creek. Retention of all sewage effluent at the surface is considered to be of principal importance. Particular care must be taken to avoid the loss of sewage effluent into the crevices immediately opposite and below the present discharge point. Rader Sink should be dammed or gated to preclude entry of stream waters during low flow conditions. Such structures should allow for flow reversals at the sink to enter the

stream. A sinkhole is located near Wilson Creek in the flood plain in the area of the proposed lagoon. Care should be taken during construction activities to avoid exposing the sinkhole in such a manner as to allow sewage effluent to enter.

2. It is recommended that special care be taken to control activities which may lead to water pollution within the internally drained areas in the project area, as identified in the Groundwater Investigation, Appendix D. This is particularly important in the source areas of Rader Spring. Land use restrictions may be necessary, and the discharge of any kind of waste water should be prohibited.
3. It is recommended that future commercial and residential developments with subsurface waste disposal facilities be constructed in such a manner as to preclude the pollution of groundwater aquifers.

Flow Augmentation

1. It is recommended that the State of Missouri and the City of Springfield request and support the early construction of the proposed County Line Reservoir on the James River, as delineated in the Comprehensive Basin Study of the White River Basin (22). Low flow augmentation in the James River as proposed in the report is necessary for the future protection and enhancement of the river below Wilson Creek.
2. It is recommended that consideration be given to providing low flow augmentation in Wilson Creek from the sewage treatment

plant down. It is possible that this could be provided by storage reservoirs on Wilson Creek above the sewage treatment plant or on South Creek. However, neither of these appear to be feasible due to geological and water quality factors. The importation of dilution water from the proposed County Line Reservoir into Wilson Creek basin is also possible. Further engineering and geological studies will be necessary to determine the most feasible means of providing flow augmentation in Wilson Creek.

Water Quality Monitoring

1. It is recommended that the Missouri Water Pollution Board, the City of Springfield, and other interested agencies monitor the quality of Wilson Creek and the James River. This would be most helpful in the evaluation of water quality improvements as the preceding recommendations are implemented and for the guidance of studies being made in the future.

HISTORY OF THE PROBLEM

Investigations have been made by various Federal, State, and local agencies following fish kills in the past. Following the fish kill in April 1954, a field investigation of the matter was made jointly by the Missouri Division of Health, the Missouri Conservation Commission, and the U. S. Public Health Service (9). The study, conducted in May 1954, noted the polluted condition of Wilson Creek, including organic sludge deposits¹ from the sewage plant (which at that time was some six miles above its present location) to the mouth. Principal contributor to the polluted condition was identified as the sewage treatment plant. Other waste sources were listed as a vitamin plant, oil from the railroad yards, cooling water from power and milk processing plants, a laundry discharge, and a very acid liquid from a phosphate fertilizer plant. No biological life was noted in the stream above the sewage plant. This was attributed to toxic materials contained in the aforementioned industrial wastes. Biological life below the sewage treatment plant was identified as generally pollution-tolerant forms.

The report of this study went on to say that observers of the fish kill reported the lethal conditions were restricted to the first 7 to 15 miles of the James River below the mouth of Wilson Creek.

The report concluded that the materials responsible for fish mortality could not be definitely established at that time. It speculated, however, that scouring of sludge deposits and sewage

¹Sludge deposits as used in this report refer primarily to the deposition on the stream bottom of solids carried over from the sewage treatment plant but also include other dead and decaying organic material.

plant bypasses could possibly cause oxygen depletion in the James River. It also pointed out that dumps of sludge by the sewage plant and accumulated wastes by industry would make the situation worse. The report also concluded that faunistic characteristics of the James River indicated that conditions fatal to fish existed for only short periods of time.

Following the two kills in 1960, a joint study of the area was made by the Missouri Water Pollution Board, the Missouri Conservation Commission, and the U. S. Public Health Service (10). The report of this study noted the polluted condition of Wilson Creek, both from industrial waste discharges and from the sewage treatment plant. At that time, the sewage treatment plant was located in its present location. Mentioned also as contributing to the pollution was drainage from a sanitary landfill located adjacent to Wilson Creek just above Scenic Avenue. Industrial wastes were listed as from a phosphate fertilizer plant, a milk processing establishment, and a livestock feed supplement factory. Characteristics of the various industrial wastes were discussed.

This study also took note of the rather unusual flow patterns in Wilson Creek, wherein part of the streamflow goes underground at two or three locations, emerging again at Rader Spring. It was pointed out that the spring had an odor identical to the odor which Wilson Creek acquired from the sanitary landfill drainage. It was stated that Rader Spring about doubled streamflow at the point of confluence, and that flow almost doubled again between Rader Spring and the mouth.

Pollution-tolerant biological life was reported as dominant in all reaches of Wilson Creek and in the James River immediately below the mouth of Wilson Creek.

Very low or absent dissolved oxygen (DO) levels occurred in all reaches of Wilson Creek, particularly at night. Nighttime levels of DO in the James River below Wilson Creek were also reported as low at low streamflow levels.

The report concluded that the available evidence pointed toward oxygen depletion as the cause of fish kills in July and August 1960, but that it was not possible at that time to trace the depletions to any specific sources. It called for the treatment of industrial wastes entering the stream in a raw state and abandonment of the sanitary landfill.

After the fish kill of July 15-16, 1966, statements were issued by the Missouri Department of Conservation (21) and by the Missouri Water Pollution Board (12). Both statements indicated the cause of the kills to be oxygen depletion. The Water Pollution Board's statement indicated that on the order of 100 times more organic matter was contributed by surface runoff from the City than from the bypass of raw and primary sewage to Wilson Creek.

The Missouri Water Pollution Board conducted another water quality study in the area during August 1966 (11). The report reviewed the 1960 study and pointed out several changes that had been made since the 1960 study. Those changes included the removal of industrial wastes from storm drains, abandonment of the sanitary

landfill, and improvements to the Springfield Southwest Sewage Treatment Plant. The 1966 report pointed also to improvements in sewage plant operating efficiency, stating that the plant had enjoyed better than 95 percent removal of biochemical oxygen demand (BOD).

The report stated that there were no noticeable sludge deposits during the study as had been observed in the 1960 study. It also pointed out that Wilson Creek flow increased from 80 percent to 1000 percent due to flow at Rader Spring, and that flow almost doubled again between there and the mouth. The report listed seven factors of consideration as contributing to the fish kills. They are:

1. Strength of the first 20 to 30 minutes of stormwater flow down Wilson Creek from runoff in the Springfield area.
2. Temperature of the first 20 to 30 minutes of stormwater flow from runoff of hot asphaltic and concrete streets and buildings in Springfield.
3. Temperature of Wilson Creek waters and of James River waters above and below Wilson Creek before the rains and reduction of temperature during the duration of the runoff.
4. Strength, volume, and timing of sewage bypass with that of the first flush of stormwater down Wilson Creek.
5. Possible entrance of slug volume of stormwater into the underground channel system pushing ahead and returning to the surface downstream, ahead of surface flow, a slug volume of the accumulated low oxygen waters.

6. The possibility of accumulation of waste solids in underground spaces and being flushed out with the increased velocity of greater flows.
7. The possibility of accumulation of wastes, dead algae, organisms, and organic solids on the bottom of Wilson Creek, especially in pools, being flushed downstream into the James River with the increased velocity of the first flush of stormwater runoff.

The report concluded that oxygen depletion, together with the shock of sudden temperature changes, was the cause of the fish kills. It further concluded that collection and treatment of primary effluent and raw sewage bypass would not have prevented the fish kills in 1960 and 1966, but that any one or more of the above listed factors of consideration could have caused a fish kill. The report advised against an impoundment above the sewage plant to trap and hold organic debris contained in the surface runoff, due to the likelihood that water low in DO would be a source of supply to the underground flow system, thereby possibly creating a worse condition than already exists.

The White River Basin Coordinating Committee has recently published their comprehensive study of the basin (22). The study calls for construction of County Line Reservoir on the James River near the Greene-Webster County line some 10 miles east of Springfield. The project would contain 190,000 acre-feet of conservation storage for water supply and pollution control and would provide a dependable yield of 100 cfs, of which about 42 cfs would be for dilution for

water quality control purposes. The actual need for dilution water was estimated in the report to be 8.65 cfs in 1968, 21.8 cfs in 2000, and about 42 cfs in 2020. These flows are average annual flows, while the bulk of the need is in the summer and early fall months.

In a hearing before the White River Basin Coordinating Committee, the City of Springfield called for pollution alleviation of Wilson Creek by flow augmentation through Wilson's Creek Battlefield National Park (8). The report pointed out the poor condition of Wilson Creek as it passes through this relatively new national park and that such condition would be repugnant to park visitors and would detract materially from the natural beauty of what will be a national shrine of historic interest. To provide the needed flow augmentation, the report cited the possibility of a storage reservoir on Wilson Creek just above the sewage treatment plant.

A report by Harvey and Skelton (6) discusses an investigation made for the City of Springfield by the U. S. Geological Survey and the Missouri Geological Survey. The investigation concerned the role of the complex, naturally developed, underground drainage system in the pollution problems associated with Wilson Creek. The study, through dye tests, seismic studies, and discharge measurements, proved the existence of the underground system. They indicated the system is recharged from sinkholes in the bed of Wilson Creek and from agricultural lands west of Springfield. The system reappears at the surface at Rader Spring, located about 1.4 miles southwest of the sewage treatment plant. The study determined that sewage effluent entered the underground system near the plant outfall, causing deterioration of the quality of the stream.

During 1967, an inspection of and report (5) on the Springfield sanitary sewerage system were made by the City's consulting engineers. In terms of hydraulic loading, the plant was at the design level of 12 MGD. In terms of BOD loading, the plant was at 81 percent of the design value. The solids loading was only slightly over design; but the report noted that when the ratio of BOD to suspended solids is high (due to strong industrial wastes with much organic material in solution) such as in the case at Springfield, a significant increase in solids occurs under aeration, converting the dissolved BOD to solid form. This condition has resulted in a solids overloading of the secondary system. BOD reduction is quite high, but solids removal is comparatively low.

The report also pointed out that the excessive flows received into the plant during rainy periods were due both to infiltration and to illegal connections of roof drain downspouts and footing drains to the sanitary sewers. It made note that this caused bypass of the treatment facilities at times.

The report concluded that design capabilities of part of the facilities have been reached and that continuing growth will overtax part of the treatment and disposal facilities in the near future.

They recommended that the City augment the program of locating and removing storm drain connections as a means of alleviating excessive wet-weather flows and that the City consider in the near future a comprehensive study of the entire sanitary sewerage system for ultimate expansion and revision of portions rapidly approaching overload conditions. They stated that such conditions are believed to be near a critical point at the Southwest Sewage Treatment Plant.

Water quality standards (13) have been adopted by the Missouri Water Pollution Board for the James River, and general criteria apply to Wilson Creek. Established water uses on the James River include irrigation, livestock watering, propagation of warm water sport fish, wildlife watering, boating and canoeing, fishing, aesthetic value, receive effluents, and receive surface runoff. In addition, industrial cooling is an established use in Lake Springfield. The water quality criteria established as standards for the James River in the study area, in addition to general criteria, include pH between 7.0 and 8.5, dissolved oxygen not less than 4.0 mg/l, and temperature not in excess of 90°F. Other specific criteria also apply to the James River.

The general criteria applicable to Wilson Creek prohibit putrescent or otherwise objectionable sludge deposits caused by waste water effluents. The stream must also be free from floating debris, oil, scum, and other floating materials attributable to waste water effluents in amounts sufficient to be unsightly or deleterious. Odors attributable to waste water effluents in such degree as to create a nuisance are prohibited. It should be pointed out that at the time the Springfield Southwest Sewage Treatment Plant was designed and approved for construction, Wilson Creek was intended for use solely to receive wastes, with protection of the James River the primary consideration. The creation of Wilson's Creek Battlefield National Park in the mid-1960's, which will ultimately contain some two miles of Wilson Creek, has changed the situation to the point that aesthetic considerations are now of importance. Aesthetics will undoubtedly

assume greater importance as the relatively new national park becomes more developed and well known and receives greater numbers of visitors.

DESCRIPTION OF THE PROJECT

Location

The study area is located in southwest Missouri, in Greene, Christian, and Stone Counties, from the City of Springfield southward to Galena. The reader is referred to the pullout location and vicinity map designated Figure 1, located in the back of the report.

The James River heads in the eastern part of Webster County some 30 miles east of Springfield. It flows in a westerly direction for about 40 miles before turning southward to flow into Table Rock Reservoir roughly 40 miles below the mouth of Wilson Creek at a point below Galena.

Wilson Creek begins with the confluence of Jordan and Fassnight Creeks on the southwest side of Springfield. Jordan Creek heads on the east and northeast side of Springfield and flows westerly and then southwesterly through the downtown area. Fassnight Creek begins on the southwest side of town and flows westerly through generally residential areas to meet Jordan Creek. Wilson Creek then flows northwestward for about 2 miles where it is joined by North Wilson Creek, which originates in northwest Springfield in and near the Frisco Railroad yards. Wilson Creek then flows generally southward for about 5 miles where it picks up the effluent from the Springfield Southwest Sewage Treatment Plant. From this point it continues southward for about 7 miles where it meets the James River.

Characteristics of the Area

The study area is in the physiographic region known as the Springfield Plateau, part of the Ozark Plateaus Province, in the White River Basin. The northern part of the area is flat to rolling, while the southern part is more hilly and precipitous. The area is underlain with limestone containing many fractures and solution channels. Sinkholes and springs are common in the area.

Rainfall in the area averages slightly over 41 inches per year, from an average low of 1.96 inches in January to a high of 5.28 inches in May. Mean annual temperature is 56.5°F, ranging from monthly means of 33.6°F in January to 78.8°F in July. However, temperatures exceeding 100°F are not uncommon in the summer months.

Elevation ranges from about 1400 feet above sea level in the upper end of the area to about 1000 feet in the lower end.

While there are ephemeral streams in the area, many other streams sustain a year-round flow due to springs and/or waste discharges. About 15 cfs of water is imported into the Wilson Creek basin for drinking water supply from the Sac River basin north of Springfield.

Land uses outside the City of Springfield include extensive forest area and a variety of agricultural uses, including dairy and beef cattle, hogs, poultry production, fruit crops, corn, and various forage and feed crops.

Springfield is a noted tourist center, being near many Ozark resort areas and Wilson's Creek Battlefield National Park. It is also an important educational center, being home to three colleges and two college-level religious training institutions. It contains a large Federal prison hospital and two other large hospitals; and the principal offices, shops, and switching yards of the Frisco Railroad are located here. Industries are many and varied and include processors or makers of cheese, whey, milk and milk products, poultry, paper cups, pharmaceutical chemicals, machine belts, typewriters, fertilizers, stainless steel tanks, flooring, truck trailers, clothing, and livestock feeds.

Springfield had a 1968 population estimated at 110,000, of which probably 95,000 reside in the James River drainage basin.

Project Work Plan

The project work plan selected for the study can be divided into three broad categories: (1) Measurement of physical and chemical parameters; (2) biological studies; and (3) a groundwater study.

Two water quality monitors capable of continuously measuring and recording dissolved oxygen, temperature, pH, and conductivity were located on Wilson Creek at the north edge of the national park and on the James River about 0.6 miles above Frazier Bridge. Late in the study the monitors were relocated to Rader Spring and to Wilson Creek just above the sewage treatment plant (see location map). A water quality monitor and its accessory equipment are shown in Figure 2. The monitors were supplemented by recording flow gages. The purpose of the monitors was to establish a relationship between

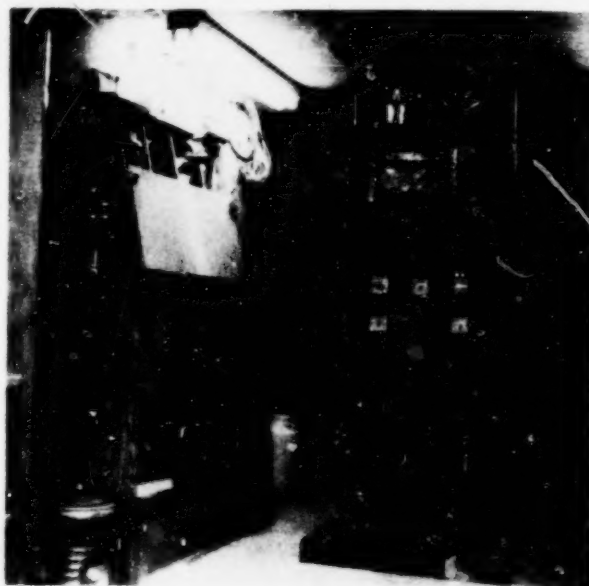
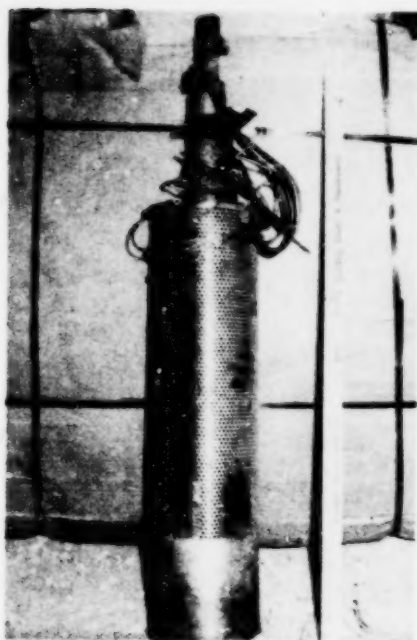
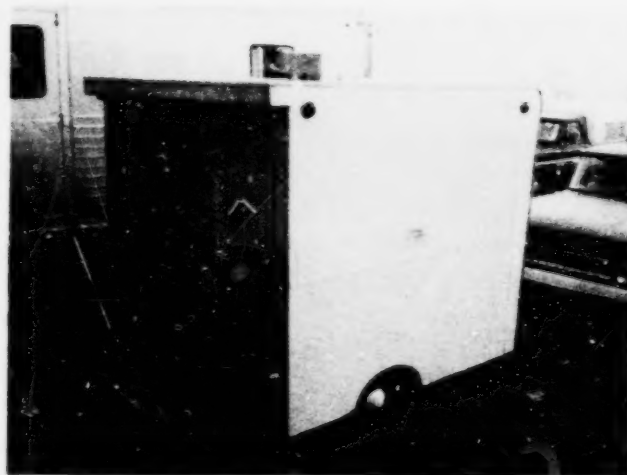


Figure 2 - Water Quality Monitor and Accessory Equipment

UPPER LEFT: Pump and pump screen UPPER RIGHT: View inside trailer

BOTTOM: Trailer used to house and transport monitor



water quality and surface runoff and streamflow. To supplement the monitors and to determine quality differences between dry-weather flow and wet-weather flow, an intensive survey of various physical and chemical parameters was conducted in July 1968. This phase was intended to determine the origin of pollutants causing or contributing to the problems being studied.

During the early planning phase of the project, some 42 possible sampling stations were selected based on their location and accessibility. These stations are shown on the Location Map, Figure 1. For various reasons, 25 of these stations were actually used for sampling. In the final selection of the sampling stations, an attempt was made to adequately cover the project area in general, to bracket the more plausible source areas of the pollutants causing the fish kills, and to identify water quality profiles and trends. A brief description of each is listed in Table 1.

Six sampling runs were made during a hot, dry period in July; and seven more sampling runs were made following general rains later in July. Parameters measured in the field include rate of flow; dissolved oxygen; temperature; pH; conductivity; and, at some stations, sulfides. Laboratory analyses included biochemical oxygen demand; chemical oxygen demand (COD); nitrate; nitrite; ammonia; organic nitrogen; phosphate; and, on the sewage samples, suspended solids.

The biological studies consisted basically of two parts, a benthic study and a fish study. They were conducted to complement

TABLE 1
Description of Sampling Stations

Station Number	Description
1	Frisco industrial waste discharge
3	MFA Plant Foods discharge (fertilizer plant)
8	Jordan Creek at Bennett Street
10	Hoffman-Taft cooling water discharge
10A	Hoffman-Taft discharge (between railroad tracks and plant)
10B	Hoffman-Taft discharge (below railroad tracks)
11	Fassnight Creek at Weller Street
12	Wilson Creek at Highway 13 Bypass
13	Wilson Creek at Highways 60 and 166
14	Wilson Creek above Southwest Sewage Treatment Plant
15	Southwest Sewage Treatment Plant influent
17	Southwest Sewage Treatment Plant effluent
20	South Creek at Road FF
21	Wilson Creek below treatment plant at flow gage
23	Rader Sink
24	Wilson Creek at Rader Bridge
25	Rader Spring
27	Wilson Creek at north edge of national park
29	Terrell Creek at Road ZZ
30	Wilson Creek at Manley Ford
33	James River below Lake Springfield
35	James River at Racetrack Road
36	Indian Spring
37	Blue Spring
39	James River at Nelson Mill Bridge
40	James River at Highway 14
41	James River at Bernet Farm

the physical and chemical data and to characterize water quality and the effects of pollution in the project area.

During the survey of bottom dwelling invertebrates, 20 stations scattered throughout the project area were sampled twice each, once in March and once in September.

The fish study consisted of five runs in late April, June, July, and August, during which time several thousand fish were collected, examined, and released.

The groundwater study was important from the standpoint that a thorough understanding of the underground drainage system was considered essential to make meaningful recommendations for corrective action. To do this, geologic mapping of the area was necessary; and the underground flow patterns were determined by water tracing using soluble dyes. Groundwater quality studies were also conducted to determine the extent of groundwater pollution which might affect Wilson Creek or the James River.

DISCUSSION

James River

The James River heads about 30 miles east of Springfield and, after flowing to a point about 12 miles southwest of Springfield, proceeds generally southward to enter Table Rock Reservoir just below Galena, Missouri. Through its entire length, the James River is an aesthetically pleasing, high quality stream. It supports one of the finest fisheries in Missouri and is an important recreational asset to the State. The river is largely spring fed but receives significant flow from surface sources, primarily Wilson Creek and Finley Creek. The river is pictured in Figure 3 at the upper end of the study area. A section of Wilson Creek is also shown.

The principal area of study during the project was from Lake Springfield dam to the monitor location at the Robert Bernet farm about 0.6 miles above Frazier Bridge. This reach encompasses about 19 river miles. Flow and water quality profiles of the James River are illustrated in Figures 4 and 5. These profile plots represent the average of all values obtained during the intense sampling phase. As indicated on the diagrams, flow increases in the river are primarily caused by Blue Spring, Wilson Creek, and unidentified springs somewhere between Nelson Mill Bridge and the Highway 14 Bridge.

The depression of dissolved oxygen below the mouth of Wilson Creek may be more significant than the amount indicated on Figure 4. Although the average grab sample DO reading was 4.9 mg/l at Bernet's

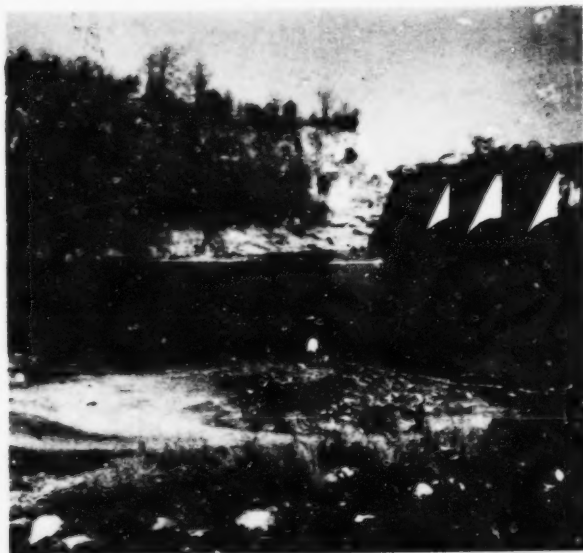


Figure 3 - JAMES RIVER AND WILSON CREEK

ABOVE: The James River at the upper end of the Study Area, just below Lake Springfield dam.

BELOW: Wilson Creek at Station 27, the north edge of the National Park. Note the supply hose running between pump and monitor.



FIGURE 4

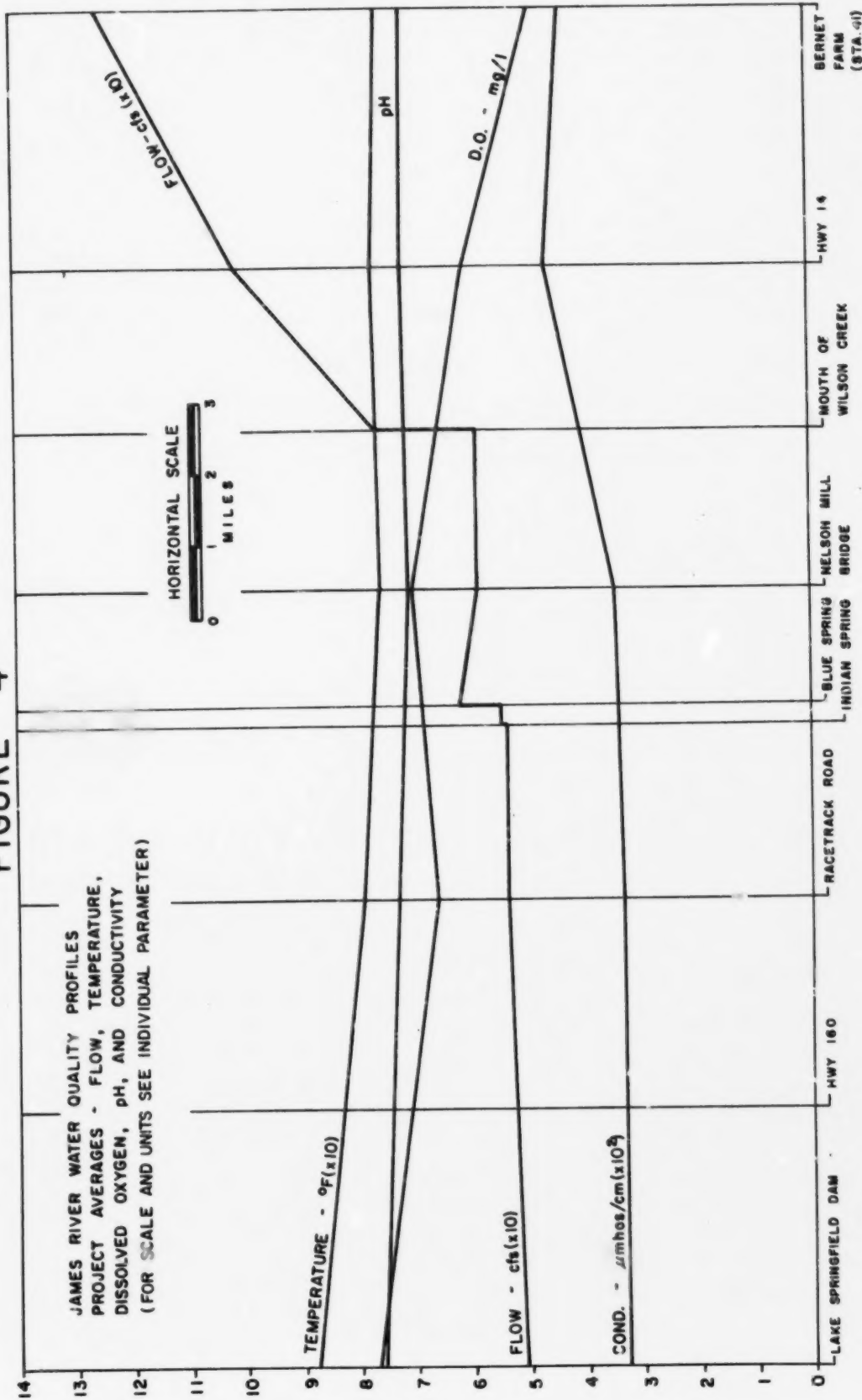
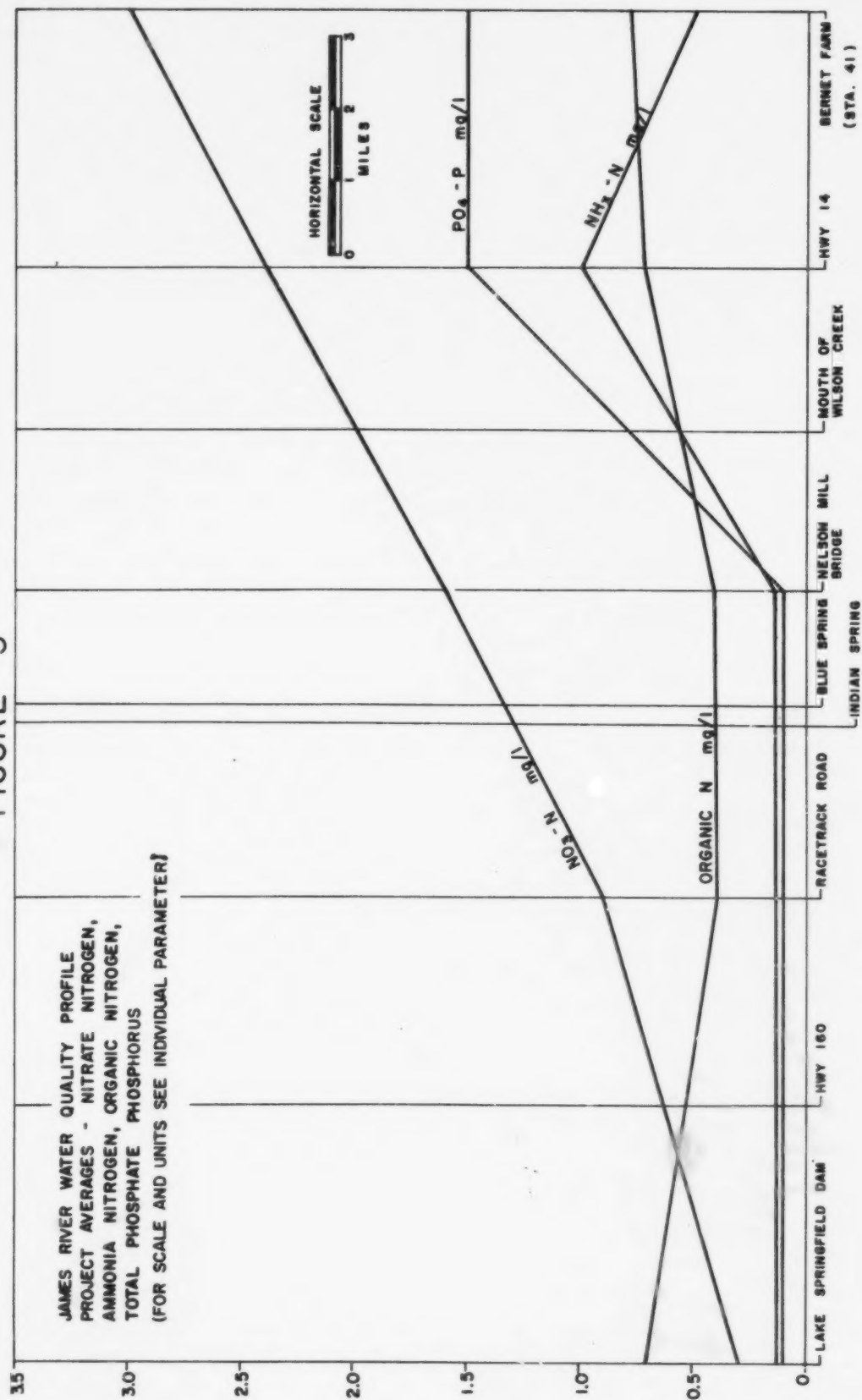


FIGURE 5



Farm, individual grab samples were measured at mid-morning as low as 3.0 mg/l. The nighttime low DO readings recorded by the monitor occasionally went down to about 2 mg/l during low flow periods. Twenty-four-hour DO studies at several stations above Wilson Creek revealed a low DO of 4.5 mg/l, with the majority of the samples being 7.0 mg/l and above. Thus, it would appear that Wilson Creek affects James River oxygen assets through the discharge of oxygen demanding materials into the river and through nighttime respiration of aquatic organisms stimulated by nutrients from Wilson Creek. The higher level of nutrients in the river below Wilson Creek is illustrated by Figure 5.

The benthos reflected some degradation or enrichment when a comparison was made of samples collected above and below the confluence of Wilson Creek (Figure 6). However, using other types of comparison, no significant differences in quality could be ascertained. No apparent difference can be seen when comparing the number of organisms per square foot and the number of benthic genera at these stations. However, when comparing the diversity of the community of invertebrates of stations above and below the confluence of James River and Wilson Creek, it can be seen that the number of pollution-sensitive organisms decrease drastically. Sensitive forms are reduced considerably at both Station 40, which is 2.3 stream miles below the mouth of Wilson Creek, and at Station 41, which is 5.5 river miles below the confluence of Wilson Creek and the James River. Pollution-tolerant forms increased in number at both of the stations.

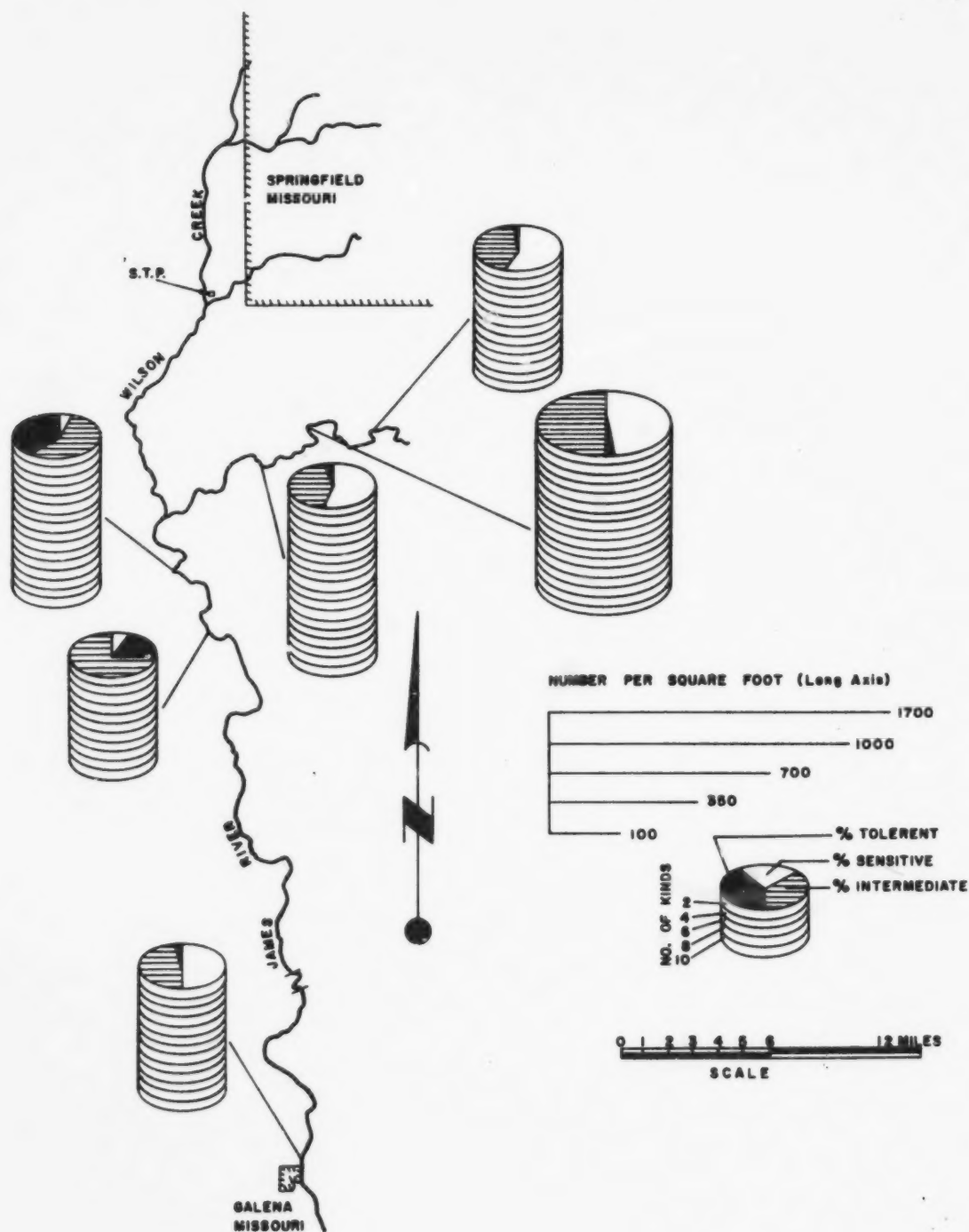


FIGURE 6 - BENTHIC ORGANISMS - MARCH & SEPTEMBER, 1968
 JAMES RIVER, SPRINGFIELD, MISSOURI

The relative abundance of benthic invertebrates collected from the James River above and below the Wilson Creek confluence did not change significantly; however, the shift in the number of sensitive forms and the tolerant forms indicates pollution of a mild nature. The pollutants are not eliminating the sensitive forms altogether; the pollutants are effecting a shift in the species dominance; tolerant forms were being favored while the sensitive forms were being restricted.

For purposes of the fish investigation, there were eight sampling stations. Three of these stations were on the James River, four were on Wilson Creek, and one was on Terrell Creek. The stations on the James River extended from river mile 72.7 to 64.0.¹ Each station consisted of approximately 3 river miles with two stations located below the Wilson Creek confluence. The stations on the James River were selected in this manner to include representative types of stream habitat at all three stations. The stations on Wilson Creek extended from stream mile 7.0, which is approximately 0.75 miles below the sewage treatment plant, to immediately below the mouth of Terrell Creek.

A total of 7,104 fish representing 43 species² were collected during the James River investigation. Figure 7 illustrates the number

¹ River miles measured from the confluence of the James River arm and main body of the Table Rock Reservoir.

² Rainbow trout were collected during this investigation below springs on the James River and Wilson Creek. There is no trout fishery on these streams; however, they were included on the species list.

— 5 — STATION NO.

NO. OF SPECIES

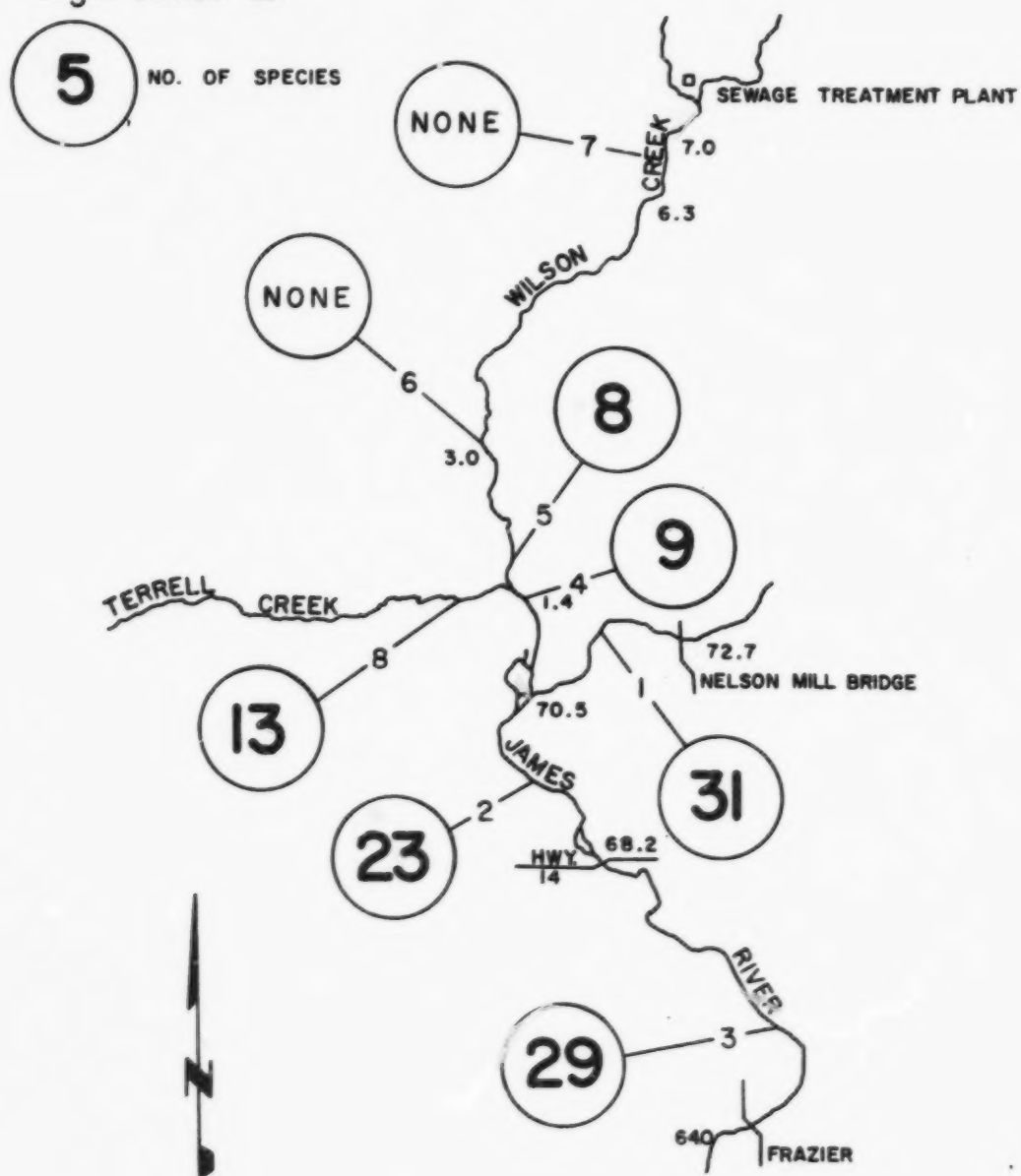


FIGURE 7 - NUMBER OF SPECIES OF FISH PER STATION.

of species found at stations on the James River, Wilson Creek, and Terrell Creek. There were more species present at Stations 1 and 3 than at Station 2, but the differences were not statistically significant. The James River had an excellent variety of fish typical of a relatively unpolluted warm water stream.

Based upon a thorough knowledge of the habitat and adequate sampling procedures, there were differences in the abundance of rough, game, and forage fish at stations on the James River. The number of rough, game, and forage fish collected per hour of electrofishing time (catch per unit effort) at each station is expressed in Figure 8.

The increase of available nutrients from Wilson Creek caused a corresponding increase in bottom-attached algae at Station 2. The dominance of rough fish at Station 2, which are omnivorous bottom feeders, reflected the fertilization effect of Wilson Creek on the James River (Figure 8). The fertilization of the James River was also reflected downstream. At Station 3, the number of game, rough, and forage fish caught per hour substantially increased compared to Station 1.

Although the rough fish increased below the Wilson Creek confluence, game fish were still significantly abundant in this area to sustain a fishery. Thus, any significant damage to the game fish population of the James River caused by pollutants discharged from the Wilson Creek watershed occurred during past fish kills, and thus was temporary.

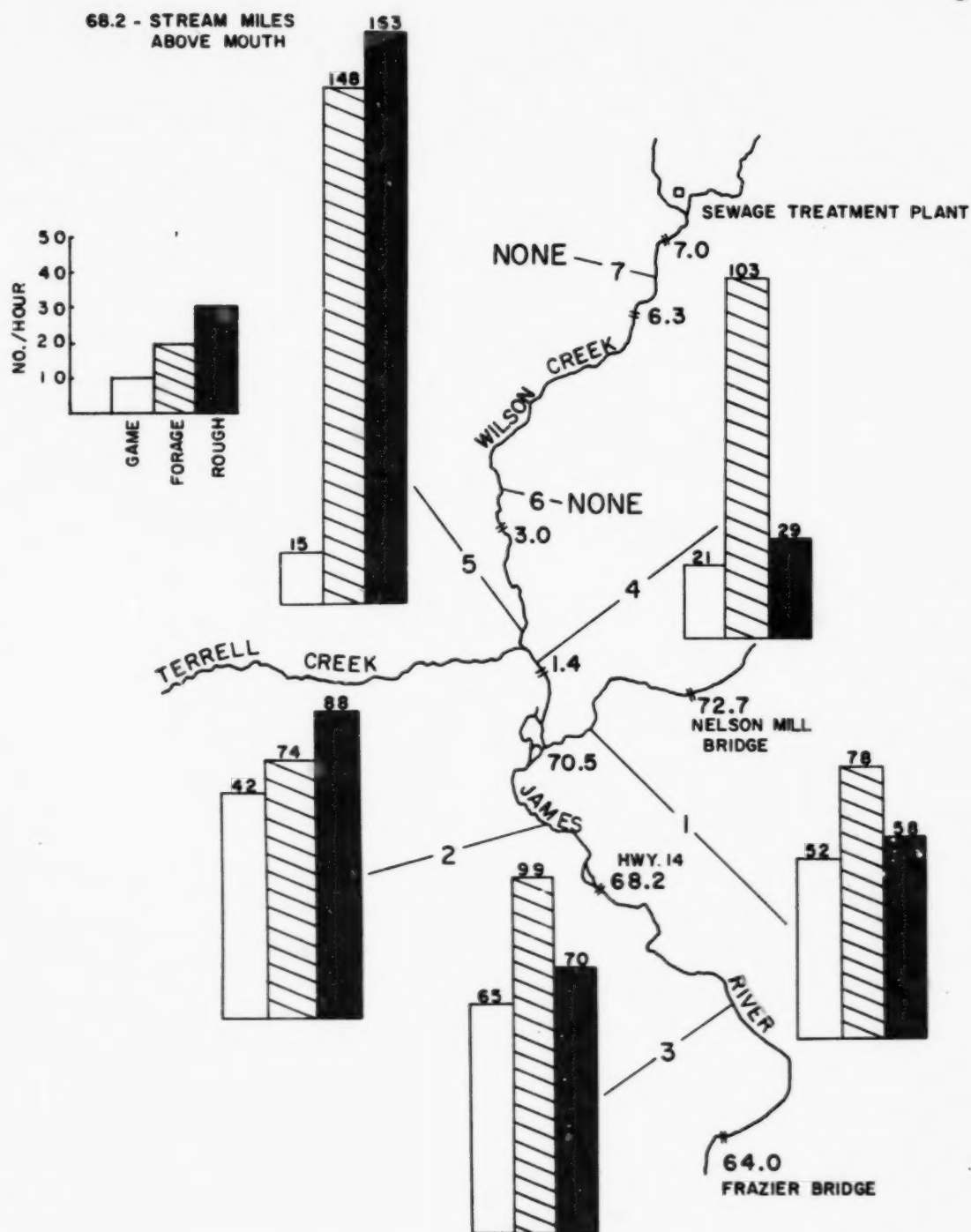


FIGURE 8 - NUMBER OF GAME, ROUGH AND FORAGE FISH CAUGHT PER HOUR AT STATIONS ON JAMES RIVER AND WILSON CREEK, MAY - AUGUST, 1968.

Desirable food and game fish such as largemouth bass, spotted bass, channel catfish, and bluegill were present at all stations on the James River. Catfish and bass comprise a major part of the sport fishery of the James River. A condition factor was calculated for these species collected above and below the Wilson Creek confluence.

The coefficient of condition (condition factor) is a numerical value used to express the relative well-being (i.e., plumpness or fatness) of fishes. It may be used to indicate suitability of environment or to compare the healthiness of fish from different areas of a stream (16). The formula $K = \frac{W (\text{weight}) \times 10^5}{L (\text{length})^3}$ was applied to bass and channel catfish taken from the James River. Weight was recorded in grams and length (total) in millimeters. These species were selected for analysis due to their prime importance as game fish.

Other factors which may affect the coefficient of condition are age, sex, and season (7). Taking these factors into consideration, the mean condition factor was calculated for bass and channel catfish taken from three stations during different sampling dates. Analyses of variance on the condition factors of these fish revealed no significant differences between stations on the basis of mean condition factors.

Lower Wilson Creek Basin

Surface and Groundwater Relationship - Wilson Creek is a study in contrasts, as illustrated by profile plots of flow and quality in Figures 9 and 10. These irregularities are primarily caused by reversible sinkholes, Rader Spring, and the discharge from the Southwest Sewage Treatment Plant.

FIGURE 9

34-B

FLOW AND DISSOLVED OXYGEN
PROFILES - WILSON CREEK
PROJECT AVERAGES

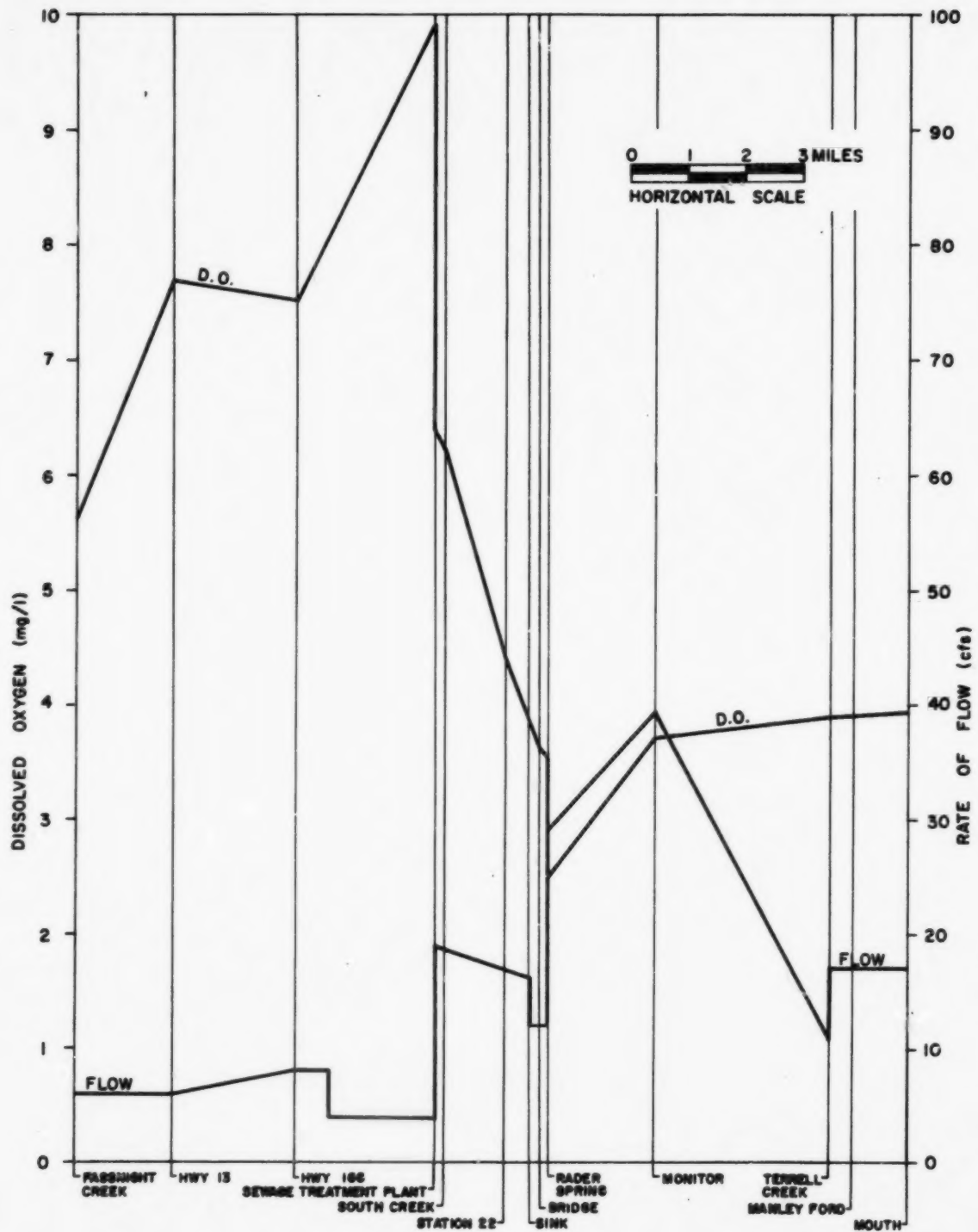
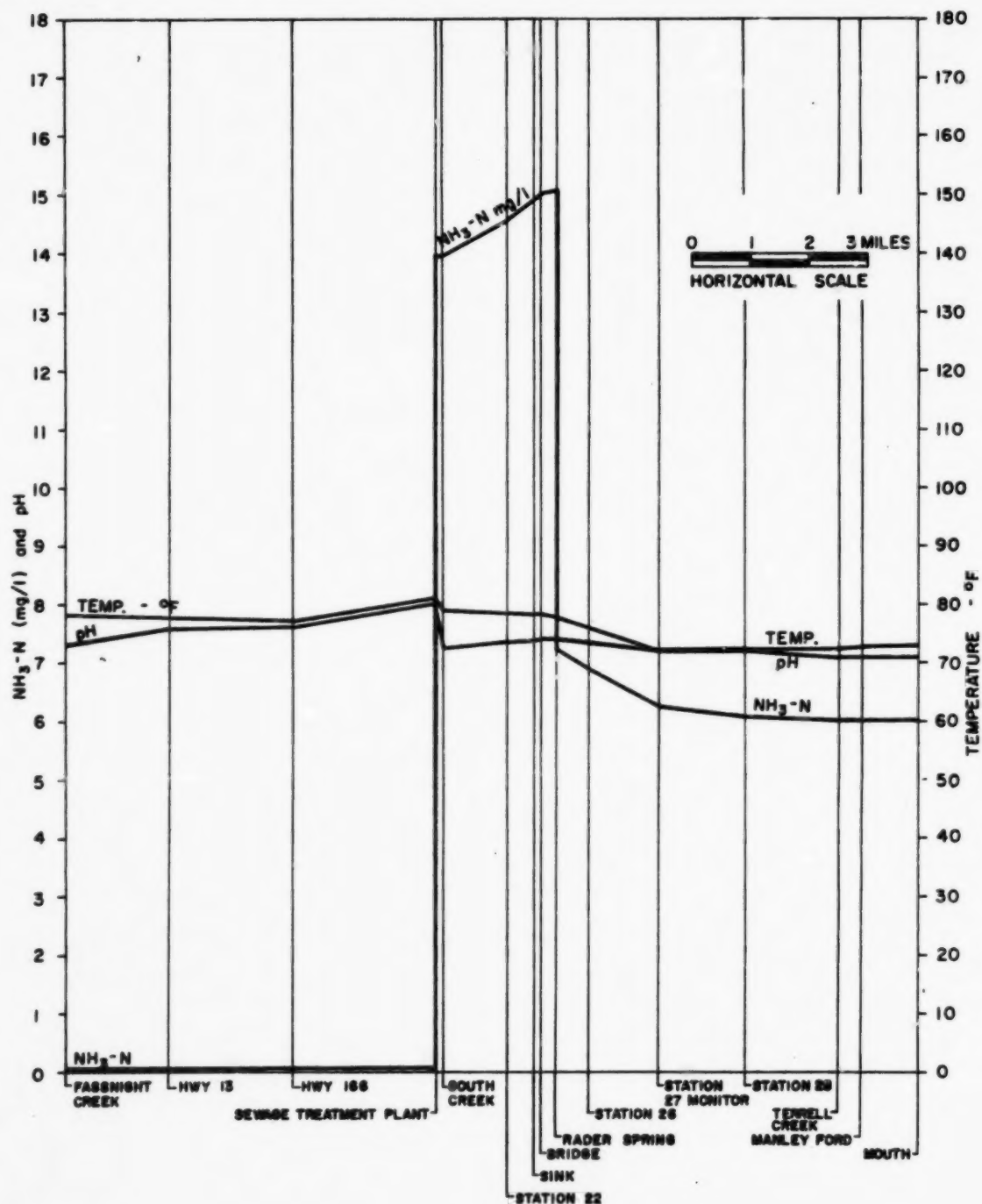


FIGURE 10

34C

AMMONIA, pH, AND TEMPERATURE PROFILES -
WILSON CREEK - PROJECT AVERAGES



Direct physical connections between surface water and groundwater at numerous locations were identified by geological and tracing studies. Hydraulically, these waters are the same system and thus are totally interdependent. Surface waters in Wilson Creek enter the ground at sinkholes 0.5 miles below Highway 166, immediately below the sewage plant discharge, and at Rader Sink, located about 800 feet north of Rader Spring. Most or all of this water returns to the surface at Rader Spring. Rader Spring is also recharged from the South Creek basin and from numerous sinkholes in the area west of Wilson Creek.

At their point of confluence, Rader Spring normally flows at a rate equal to or greater than that of Wilson Creek, and thus has great influence on the quality of the stream below that point. The sewage plant discharge in turn has a profound effect on both Rader Spring and Wilson Creek.

During 1967, a series of flow measurements by the U. S. Geological Survey (6) at various seasons and rates of streamflow showed the loss of from 5 to 11 cfs to the sinkhole just below the sewage plant outfall. Since the great bulk of flow at that point is sewage effluent during low flow conditions, it can be assumed that most of the loss to the sinkhole is treated sewage.

Odor Problems - During the fall and winter of 1967, Rader Spring was observed several times by project personnel to have a strong septic odor and many organic solids in suspension and was supporting luxuriant growths of *Sphaerotilus*, a sewage fungus. City of Springfield

personnel reported that on several previous occasions, measurements had indicated a complete lack of dissolved oxygen.

However, during the summer and fall of 1968, the appearance and quality of Rader Spring improved a great deal. The *Sphaerotilus* disappeared; odors were almost nonexistent; no solids were in evidence; and dissolved oxygen, although low, was always present. The benthic community was still dominated by pollution-tolerant forms.

The reason for this improvement was determined to be the stoppage, or partial stoppage, of the crevices just below the sewage plant outfall, thus greatly reducing the volume of sewage effluent going underground at that point. The reduction of flow into the crevices was indicated by discharge measurements made by project personnel in August and from continuous discharge measurements provided by the U. S. Geological Survey in September 1968. However, due to the flow-reversible nature of the lower elevation sinkholes, the stoppage cannot be considered permanent. Basin-wide groundwater quality studies revealed no other significant sources of groundwater pollution which might affect the quality of Wilson Creek.

This lack of strong septic odors in Wilson Creek during the study period largely negated the odor control objectives of the project. However, for exploratory purposes, samples were taken and analyzed for actinomycetes, an odor producing group of bacteria, on two different occasions at ten stations ranging from above the sewage plant to near the mouth of Wilson Creek. All samples for actinomycetes

were negative. It should be pointed out, however, that weak to mild sewage odors remain in Wilson Creek at times, from the sewage plant to the mouth.

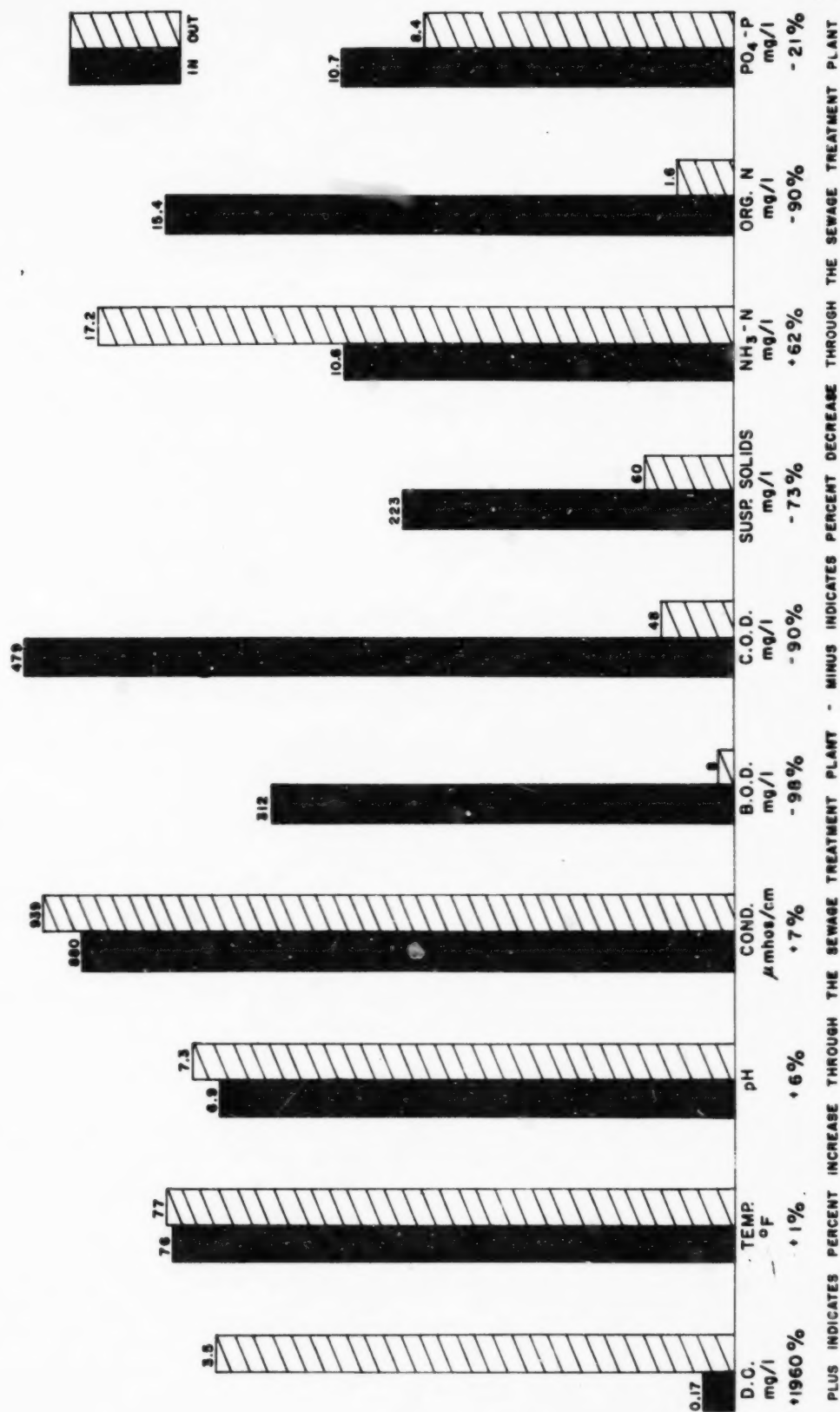
Springfield Southwest Sewage Treatment Plant - The Springfield Southwest Sewage Treatment Plant is located at the confluence of South Creek and Wilson Creek, some 8 miles above the mouth of Wilson Creek. Built in 1959, it is an activated sludge plant and uses the Kraus process in which digester supernatant is returned to the reaeration tanks as a nutrient. With subsequent modifications following initial construction, plant design flow is 12 MGD (hydraulic design flow is 16 MGD) (5). Organic design loading capacity is for an average population equivalent of 250,000 persons (about 42,500 lbs/day BOD). Overall design removal is 95 percent for both BOD and suspended solids.

Due to roof drains, other stormwater connections, and infiltration into the sanitary sewer system, the capacity of the sewage treatment plant is frequently exceeded during periods of rain. When the rate of flow into the plant exceeds about 16 MGD, excess inflow up to about 27 MGD receives only primary (sedimentation) treatment. Excess over 27 MGD is discharged raw into Wilson Creek. The City has plans to install a 10-acre polishing lagoon into which the final effluent will be diverted. All plant bypasses will also enter the pond.

During normal operations, the plant is quite efficient in the removal of oxygen demanding materials as measured by BOD and COD (Figure 11). Over the course of the field sampling, reduction of

FIGURE II

SEWAGE TREATMENT PLANT EFFICIENCY - PROJECT AVERAGES
FLOW AVERAGE = 11.1 MGD



BOD averaged 98 percent and COD reduction averaged 90 percent. Removal of suspended solids was somewhat lower at 73 percent reduction. However, scrutiny of plant operation reports from April through December of 1968 indicates BOD removals averaging 93 percent and suspended solids removals of 85 percent. Organic nitrogen removal averaged 90 percent, but the plant effluent contained an average concentration of ammonia (expressed as elemental nitrogen) of 17.2 mg/l.

One factor which undoubtedly affected data on the sewage treatment plant was that one of the largest single contributors of industrial wastes to the system, Hoffman-Taff Pharmaceutical Chemical Company, was operating at only one-fourth capacity at the time of the study.

Table 2 is a summary of overall project averages of the various physical and chemical indicators of water quality and rates of flow of the sewage treatment plant and all other stations.

The effect of the sewage treatment plant discharge on the quality of Wilson Creek is evident from Figures 9 and 10. Very little benefit from dilution is available, and the percentage of treated sewage in the stream below the plant ranges from 80 to 100 percent for a large part of the year. Although the plant currently provides a high degree of treatment, stream conditions reflect a polluted condition. Daytime levels of dissolved oxygen generally exceed 2 to 3 mg/l, but nighttime levels often fall to 1 mg/l or less. Levels of ammonia for about 2 miles below the plant outfall average from 14 to 15 mg/l. Dilution by Rader Spring lowers this

TABLE 2

Overall Project Averages of the Various Physical and Chemical Indicators of Water Quality and Rates of Flow

Station	Description	Flow cfs	D.O. mg/l	D.O. % sat.	Temp. °F	pH	Cond. µmhos/cm	KOD mg/l	CO ₂ lbs/day	NO ₃ -N mg/l	NO ₃ -N lbs/day	Org-N mg/l	NO ₃ -P mg/l	NO ₃ -P lbs/day
1	Frisco discharge	1.15	0.0	0	83	8.3	745	90	559	155	963	3.23	2.1	1.16
3	HFA Fertilizer	0.225	3.2	38	78	2.6	5150	<25	<30	47	57	330	9.3	86.78
8	Jordan Creek at Beusett	6	5.6	66	78	7.3	472	6	194	30	972	0.7	22.7	15.9
10	Hoffman-Teff Cooling Meter	0.15	6.5	74	72	7.2	317	24	19	37	30	0.41	0.33	0.1
10A	Hoffman-Teff above Railroad	0.8	5.9	73	81	7.6	316	<25	<108	11	48	0.49	2.12	1.06
10B	Hoffman-Teff below Railroad	0.1	3.0	35	75	6.9	523	25	14	30	16	1.54	0.83	0.19
11	Peasnight Creek at Heller	1.5	6.4	82	84	7.5	526	5	40	14	113	0.49	3.97	9.2
12	Wilson Creek at Highway 13	6	7.7	93	78	7.6	476	5	162	21	640	0.71	23	9.7
13	Wilson Creek at Highway 166	8	7.5	89	77	7.6	446	<5	<216	25	1,080	0.67	28.9	11.7
14	Wilson Creek above STP	3.9	9.9	123	81	8.0	379	<5	<105	27	568	0.49	14.53	5.05
15	STP Influent	17.2 (11.1820)	0.2	2	76	6.9	880	312	28,979	479	44,490	15.4	1,430	984
17	STP Effluent	17.2 (11.1820)	3.5	42	77	7.3	939	8	53	48	4,458	1.6	149	760
20	South Creek at Road 77	1.7	9.2	114	80	7.8	506	5	44	13	119	0.52	4.77	4.04
21	Wilson Creek below STP	19.4	6.2	76	79	7.2	781	8	838	47	4,926	1.1	115	738
23	Radar Sink	4.6	3.6	44	80	7.4	797	11	273	45	1,118	1.87	46	174
26	Wilson Creek at Radar Bridge	11.5	3.7	45	79	7.4	803	11	683	45	2,795	1.75	108.7	478
28	Radar Spring	17.4	1.8	20	68	6.8	580	5	470	17	1,597	0.46	43.2	254
27	Wilson Creek at Monitor	39	3.7	42	72	7.3	683	6	1,483	30	6,318	1.01	213	842
29	Terrell Creek at Road 22	6.2	8.4	91	67	7.2	421	<5	<187	4	134	0.1	3.4	5.7
30	Wilson Creek at Mintley Ford	17	3.9	44	72	7.1	621	7	643	26	2,203	0.8	73	303
33	James River below Lake	51	7.7	103	88	7.6	324	<5	<1,377	15	4,131	0.72	198	33
35	James River at Beestrock	54	6.6	80	79	7.3	336	<5	<1,458	9	2,424	0.38	111	29
36	Indian Spring	0.9	8.3	91	58	6.4	413	<5	<34	4	19	0.1	0.5	0.4
37	Blue Spring	7.1	8.6	84	58	6.8	409	<5	<192	4	153	0.1	3.8	3.1
39	James River at Wilson Mill	59	7.1	84	76	7.1	348	<5	<1,593	9	2,867	0.41	131	29
40	James River at Highway 14	101	6.1	73	77	7.2	445	6	3,272	19	10,363	0.73	398	813
41	James River at Monitor	126	4.9	58	76	7.2	441	5	3,402	19	12,928	0.78	531	987

Note: Many of the values in the table are approximations due to "less than" values obtained during laboratory analysis.

to about 7 mg/l, but levels of 6 mg/l persist all the way to the mouth. These concentrations of ammonia with the attendant pH and temperature conditions are known to be toxic to many species of fish (18). In addition, the toxicity of ammonia is greatly increased at low levels of dissolved oxygen.

For a distance of 4 or 5 miles below the plant, rather extensive deposits of sludge are in evidence. From the plant to the mouth, rocks on the stream bottom are coated with heavy growths of blue-green algae, apparently stimulated by the high concentration of ammonia discharged from the sewage treatment plant. Both the sludge deposits and the blue-green algae are indicative of anaerobic conditions at the stream-bottom interface.

Comparing biological data above and below the sewage treatment plant (Stations 14 and 21, respectively) illustrates the gross pollution below the sewage treatment plant. Eleven different kinds of bottom dwelling invertebrates were collected above the plant while only three different kinds were collected below the plant. Above the plant, 70 organisms per square foot were collected as compared to 853 organisms collected below the plant. All organisms collected below the plant were tolerant forms while only 17 percent of those collected above the plant were tolerant.

The biological data show that polluted, but slightly improved, conditions exist all the way to the mouth. Figure 12 illustrates the extent and type of benthic organisms in Wilson Creek and its tributaries.

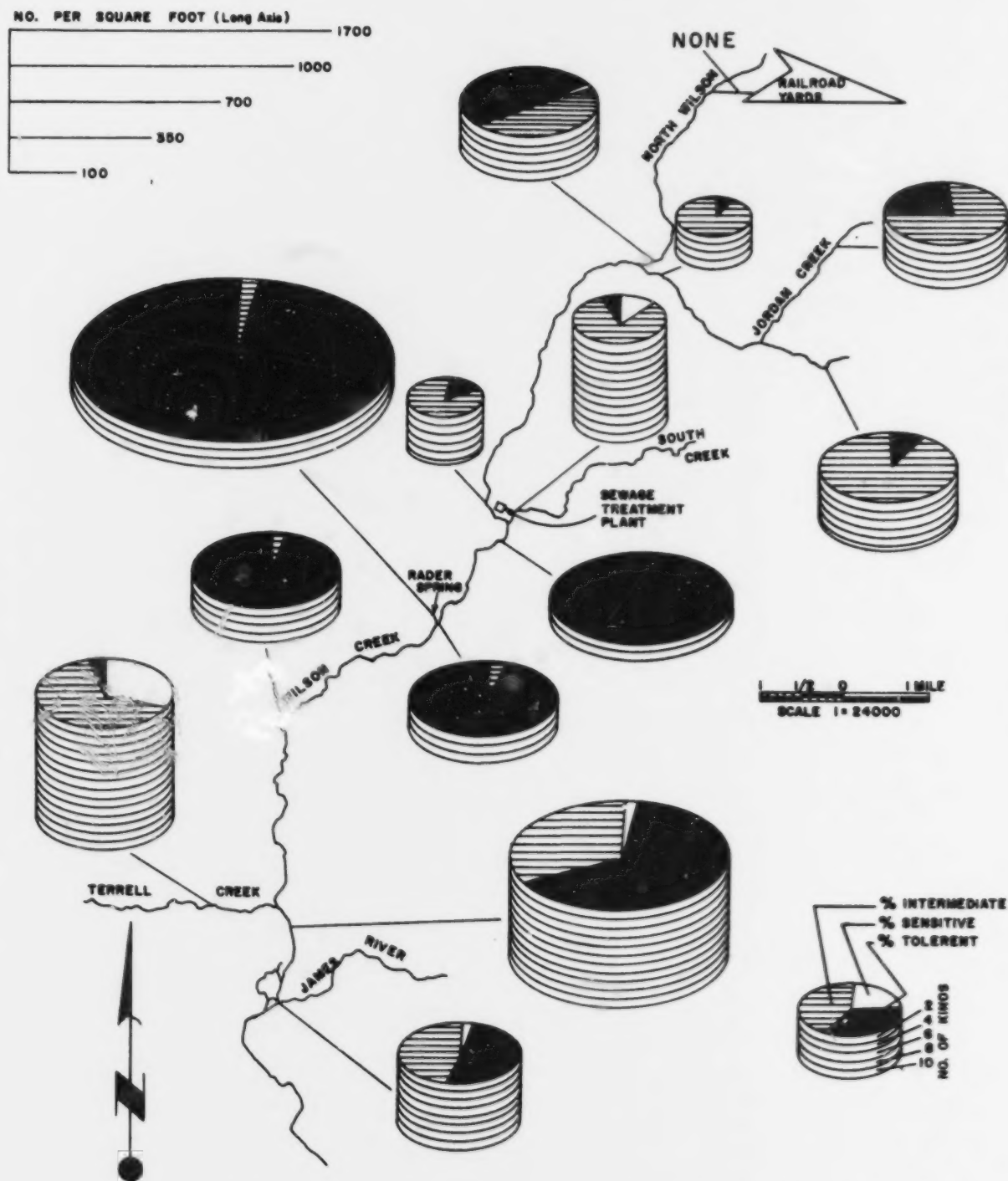


FIGURE 12 - BENTHIC ORGANISMS - MARCH & SEPTEMBER, 1968
WILSON CREEK & TRIBUTARIES, SPRINGFIELD, MISSOURI

The polluted condition of Wilson Creek was also confirmed by the fish investigation. No fish were collected above stream mile 1.5 (influence of Terrell Creek) on Wilson Creek due to the poor quality water. Fish collected below stream mile 1.5 reflected improved, but still degraded, conditions. Terrell Creek, a spring-fed tributary to lower Wilson Creek was determined to be a high-quality stream. This is supported by all chemical and biological data obtained during the study.

Upper Wilson Creek Basin

Jordan-Upper Wilson Creek - Jordan Creek heads in the far eastern edge of Springfield and flows westerly through the center of the commercial and industrial area of the city. Near the southwest edge of Springfield at the mouth of Fassnight Creek, it becomes known as Wilson Creek. Biological studies reflect a somewhat degraded condition in the downtown area. The stream is fed by springs, but dry-weather flow ($\approx 3-5$ cfs) is largely sustained by cooling water discharges from a number of industrial establishments. The water is clear, and the concentration of nutrients is sufficient to grow enormous quantities of algae very rapidly. This algae forms into thick mats in quiescent areas and in places, chokes the entire cross section of the stream. Several industrial concerns are located in the Jordan-Upper Wilson Creek basin. The more significant wet industries are:

Hoffman-Taff Pharmaceutical Chemical Company - Located at the confluence of Jordan and Fassnight Creeks where the streams become

known as Wilson Creek, Hoffman-Taff discharges its process wastes to the sanitary sewer while cooling waters and small volumes of miscellaneous other plant wastes are discharged to the stream.

Volume of process waste ranges from about 40,000 gpd to 150,000 gpd, and averages 100,000 gpd. The company provides pre-treatment facilities which consist of a 400,000-gallon pond followed by an aeration tank (12-hour retention) and a sedimentation basin. The discharge to the sewer, following pre-treatment, has a BOD of about 2300 mg/l. At a volume of 100,000 gpd, this waste discharge represents 4 to 5 percent of the total organic load entering the Southwest Sewage Treatment Plant.

During the intensive sampling phase of the study in July, three different locations where cooling waters and other wastes enter the stream from Hoffman-Taff were sampled although the plant was operating at about one-fourth of capacity. Although the data thus attained generally indicate no unusual conditions or strong wastes, one sample of the cooling water discharge had a BOD of greater than 81 mg/l and a COD of 106 mg/l, indicating possibly a contamination of the cooling water with a process chemical on that one occasion.

The probability of pollution of Wilson Creek in periods of high water is a point of concern. Hoffman-Taff is in the flood plain of Jordan-Wilson Creek. Many hazardous chemicals are utilized as raw materials at the plant. During the industrial waste survey of Hoffman-Taff, several dozen barrels of cyanide compound were

being stored on the premises at ground level. In addition, the process waste pond is located immediately adjacent to the stream. The release of the 400,000-gallon contents of the pond plus many barrels of some hazardous chemical to the stream during flood stage is not at all a remote possibility. In a report concerning flooding along Wilson Creek (19), it is mentioned that flood waters were waist deep at the Hoffman-Taff plant during a 1951 flood. A newspaper story on the flood, as carried in the report, stated "...Most extensive damage was caused at Hoffman-Taff, Inc., a pharmaceutical manufacturing plant. Hundreds of drums of valuable chemicals were carried away by the flash flood."

The report further indicates that even larger floods can reasonably be expected to occur in the future. The flood whose magnitude represents the reasonable upper limit of expected flooding would inundate the Hoffman-Taff plant area to a depth of nearly eight feet.

MFA Plant Foods (Fertilizer Manufacturer) - Waste water from this fertilizer plant consists primarily of scrubber water containing a gypsum sediment, heavily laden with nitrogen and phosphorus. Wastes flow from the plant in an open ditch to a series of three small ponds adjacent to the south fork of Jordan Creek. Overflow from the third pond enters the stream. Volume of waste being discharged varies considerably. At times there is no discharge. Storm runoff from the plant site and immediate surrounding area flows into the raw waste ditch and enters the pond system, at times causing overflow to the

stream. Heavy runoff sometimes causes a breach in the pond dikes, allowing sediment and other materials to enter the stream. Nutrients in the discharge undoubtedly stimulate the heavy algal growths downstream.

Conductivity of the waste discharge averaged over 5000 micromhos per centimeter during periods when a discharge was occurring. Nitrates (as N) averaged 14.7 mg/l, ammonia (as N) averaged 272 mg/l, organic nitrogen averaged 9.3 mg/l, and total phosphate (as P) averaged 86.8 mg/l. The concentration of phosphate (as P) on two occasions exceeded 200 mg/l. The pH averaged 2.6. Sulphuric and phosphoric acids are among the basic raw materials used in the fertilizer manufacturing process.

MFA Packing - All process wastes and wash waters from this packinghouse and rendering plant enter the sanitary sewer. Volume runs about 70,000 gpd, and the BOD load is about 400 lbs/day. Some feed pen manure (60-100 head) could drain into the south fork of Jordan Creek during rainy periods, but this should not be a problem with good housekeeping practices.

Harker Paint Company - Located adjacent to the south fork of Jordan Creek, this company allowed significant volumes of paint to enter the stream during the study. On one occasion, the stream bottom was coated for several hundred feet with the paint.

Foremost Dairies - Process wastes from this milk processing plant enter the sanitary sewer. The wastes consist primarily of rinse-down and cleanup water. A small volume of bleedoff from the

cooling water system enters a storm sewer which enters Jordan Creek at Station 6.

Producers Creamery - Discharging process wastes to the sanitary sewer at a rate of 150,000 gpd, this plant contributes 2,000 lbs/day BOD load to the system. Cooling water blowdown enters a storm sewer which enters Jordan Creek at Station 7.

Producers Produce - Process wastes from this turkey and chicken processing establishment add a BOD load to the sanitary sewer of about 250 lbs/day on an annual average basis. Blood, feathers, and offal are taken to a rendering plant. Cooling water blowdown at the rate of 250 gpm enters a storm sewer which flows into Jordan Creek at Station 6.

Fassnight Creek - Heading in the eastern part of Springfield south of Jordan Creek headwaters, Fassnight Creek flows westerly to join Jordan Creek in southwest Springfield. From this confluence down, the stream is known as Wilson Creek. Fassnight Creek has a much different type drainage basin than Jordan Creek. The watershed is primarily residential, although significant areas of industrial and commercial concerns are present in the basin. The only station sampled on this stream indicates an acceptable level of quality exists, except for occasional oil spills in upstream areas. However, no pollution-sensitive biological organisms were found in Fassnight Creek.

Fassnight Creek basin industries are:

Kraft Foods - This cheese manufacturing plant discharges

approximately 160,000 gpd of process waste to the sanitary sewer, with a BOD load of about 1100 lbs/day. Peak season is April through September. Cooling water blowdown enters Fassnight Creek through a storm sewer at a volume of 150 gpm and constitutes most or all of the flow in the creek at that point during dry weather conditions.

Kraft Industrial - Utilizing whey from the cheese plant, Kraft Industrial makes instant milk. All liquid wastes from the plant enter the sanitary sewer. The process waste volume is about 200,000 gpd and has a BOD load of 4300 lbs/day. Cooling water blowdown volume is 30 to 50 gpm.

North Wilson Creek - North Wilson Creek heads in northwest Springfield in and around the Frisco yards and shops. Dry-weather flow is sustained largely by the industrial waste discharge from the Frisco facility. As discussed below, this water is of extremely poor quality and is highly toxic toward aquatic life. In dry-weather periods, a considerable amount of quality improvement takes place in the 3-mile length of North Wilson Creek and in the first 2 miles of Wilson Creek below their confluence due to the process of natural stream purification.

St. Louis-San Francisco (Frisco) Railroad - Located at the headwaters of North Wilson Creek, the principal function of this facility is maintenance and care of diesel engine locomotives. Wastes consist primarily of diesel fuel oil spillage, oil, engine cooling water containing corrosion inhibitors (sodium borate and sodium nitrite), and a variety of emulsifiers, solvents, soaps, wetting

agents, acids, alkalies, and foam producers. The compounds have various levels of toxicity toward aquatic life, and whatever synergistic or antagonistic effects exist are unknown. Waste volume during the sampling period averaged roughly 0.8 MGD, but volume normally averages 0.2 MGD. Treatment facilities consist of a gravity oil separator, followed by a holding pond with a capacity of about 1.5 million gallons. The pond discharge is dosed with 60 mg/l ferric sulfate and directed through a final long, narrow pond in an attempt at further clarification. The final pond is essentially a wide spot in the effluent ditch.

Stormwater runoff from a large portion of the yard and shop area flows into the waste treatment area. The oil separator is equipped with a high level bypass; and storm runoff and wastes flow around the first pond, through the second small pond, and into the stream. A considerable amount of settled waste material is undoubtedly scoured into the receiving waters during periods of runoff, even though the small final pond is occasionally cleaned.

Water quality data on the waste discharge show an almost complete lack of oxygen. The median value of BOD concentration was 51 mg/l, but the average was 90 mg/l due to one occasion following a heavy rain when the BOD measured 533 mg/l. The COD values ranged from 106 to 193 mg/l and averaged 155 mg/l. The toxic nature of this discharge is indicated by a complete absence of bottom-dwelling invertebrates in the drainage ditch just below the discharge.

South Creek - South Creek heads in southeastern Springfield and flows generally westerly to join Wilson Creek at the sewage treatment plant. The basin is largely residential and rural, but some commercial development has taken place. South Creek receives the cooling water discharge from Springday Rubber Company.

Roughly 30 percent of the basin drains internally into upper basin sinkholes, most of which resurfaces at Rader Spring. The balance of basin drainage, except during periods of high runoff, enters sinkholes in the streambed, the last about 500 feet above the mouth. This water also surfaces at Rader Spring.

The quality of South Creek, as measured during the study at Road FF, is good. A balanced complement of sensitive, intermediate, and tolerant bottom dwelling invertebrates was collected.

Springday Rubber Company - This manufacturer of machine v-belts has no liquid process waste. They formerly experienced the intermittent loss of rubber dust to South Creek, but this problem has been corrected. Cooling waters are discharged to South Creek at the rate of about 3 MGD. There is a small amount of oil which contaminates this cooling water at times. Floor drains in the original plant discharge to the stream, which would allow spilled solvents or other harmful chemicals to enter the stream.

Stormwater Runoff-Water Quality Relationships

The primary concern of this study was to determine the reason for occasional fish kills in the James River. The kills were known to be associated with storm runoff. As previously stated, this

involved determining why the fish die and the source of pollutants causing the kills. From review and consideration of previous studies, slugs of low DO were strongly suspected to be the cause of the fish kills. Four source areas of the pollutants causing the kills were considered plausible. They were: (1) runoff from the upper Wilson Creek basin; (2) sewage treatment plant bypasses; (3) scour by storm runoff of oxygen demanding sludge deposits in the bed of Wilson Creek below the sewage treatment plant; and (4) large slugs of septic water from Rader Spring and Rader Sink during rainy periods in its source areas. The two water quality monitors were heavily relied upon to supply the answers.

Continuous Measurement of Streamflow and Quality - From May 1, 1968, until September 10, 1968, the two water quality monitors were located on the farm of Ray Hampton on Wilson Creek at the north edge of the national park (Station 27) and on the farm of Robert Bernet on the James River (Station 41). They were relocated on September 10, 1968, to Rader Spring (Station 25) and to Wilson Creek above the sewage treatment plant (Station 14) where they remained until October 24, 1968. Figure 13 illustrates the four monitor locations.

A consistent relationship between stream quality and storm runoff was soon determined to exist in Wilson Creek. Examination of the strip chart of the monitor located at Station 27 showed that as the leading edge of runoff comes by, dissolved oxygen concentration rapidly falls from its preexisting level to some lower level, usually between 0.1 to 0.5 mg/l. Most of the drop in DO comes within a matter of 5 to 10 minutes. After staying at this low level for some

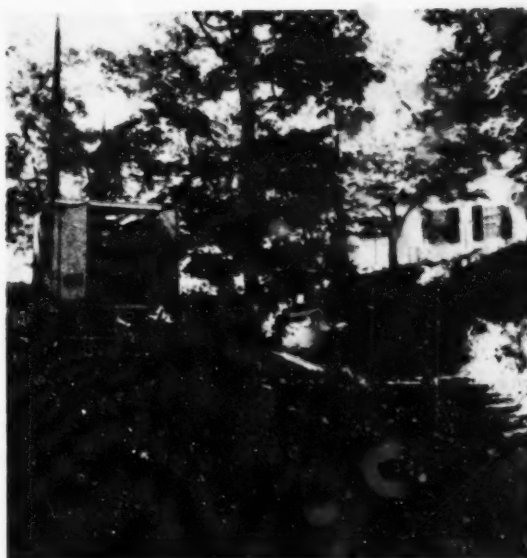
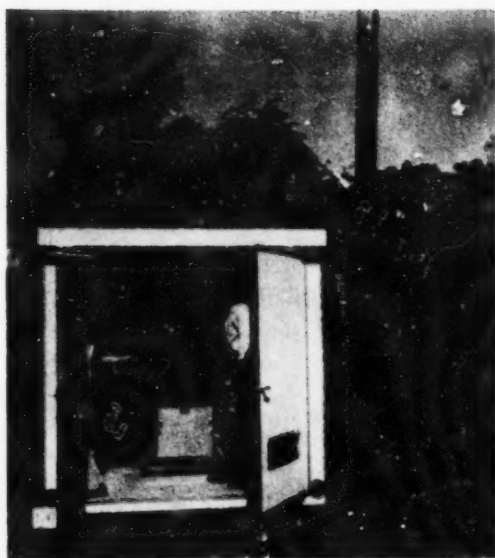


Figure 13 - MONITOR LOCATIONS

UPPER LEFT: Monitor installation on Wilson Creek at Station 27. Wilson Creek out of sight in the background. UPPER RIGHT: Monitor installation on the James River at Station 41. James River about 50 feet behind camera. LOWER LEFT: Monitor installation on Wilson Creek above the sewage treatment plant. Monitor was located on plant grounds, but pump was located in the stream above the influence of the plant discharge. Supply line is visible in foreground. The stream is 50 feet behind camera. LOWER RIGHT: Rader Spring. The pump was submerged in the spring, with monitor just above the top of the picture.



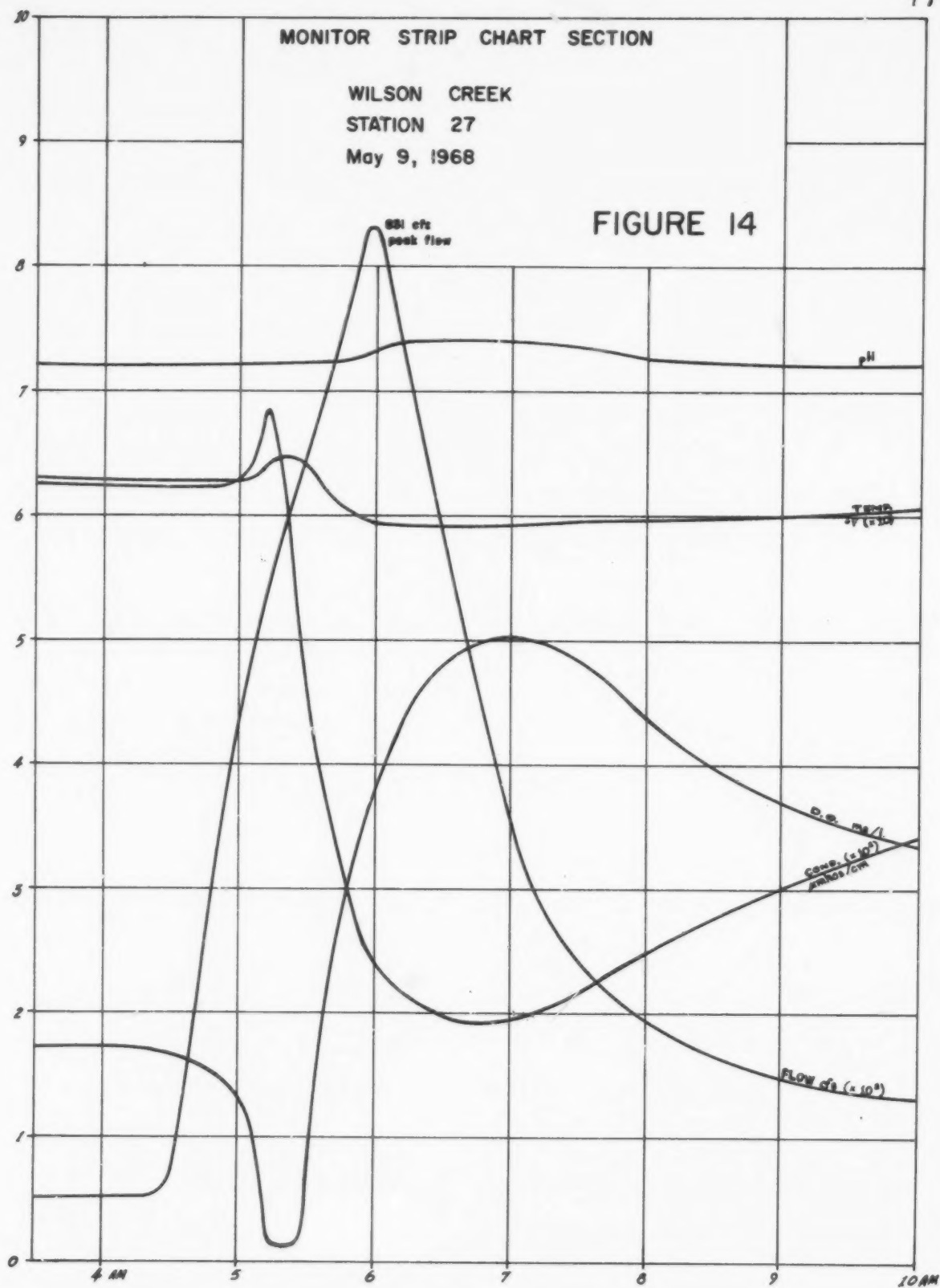
15 to 20 minutes, DO will very rapidly increase back to its pre-existing level or higher before returning slowly to a normal level. Conductivity is practically a mirror image of DO, first rising slightly before rapidly falling. Temperature and pH generally increase slightly, then decrease slightly. A graphical illustration of this relationship is shown in Figure 14.

The reader is referred to the section headed "Selected Monitor Strip Chart Records" near the end of Appendix A, Volume II. These records show the quality changes that occur with various levels of runoff as well as diurnal changes with a relatively constant flow.

Examination of the records for Station 27 indicates that the magnitude of quality changes is somewhat dependent on the volume of runoff, and that small quantities of runoff may produce little or no change in quality. The period of time since the preceding flushing rain also influences the magnitude of water quality changes.

At the James River monitor location (Station 41), very little of the effect noticed on Wilson Creek occurred, primarily due to higher flows in the river. However, the strip chart data indicate that at lower river stages slugs of low DO water caused by heavy runoff in the Wilson Creek basin would persist for several miles down the James River. As discussed in the Introduction, during very low flow conditions in the river and with heavy runoff down Wilson Creek, Wilson Creek flows may exceed James River flow by as much as 40 to 1 for brief periods of time.

49-B



Early in September the two monitors were relocated. One was placed at Rader Spring to determine the role of the spring in causing or adding to the slugs of low DO water. As can be seen from the strip chart records, flow increases at the spring caused very minor quality changes during the period of measurement, certainly not enough to produce the observed effect downstream at Station 27 on Wilson Creek. However, should Rader Spring return to its pre-study septic condition (as discussed earlier), it is reasonable to assume that it could produce or contribute to such effect.

The other monitor was relocated on Wilson Creek at Station 14 just above the sewage treatment plant to determine the effect of storm runoff from the upper Wilson Creek basin. Although the DO did not drop to very low levels as the storm runoff passed by, there are indications that it would do so under the proper conditions. A slow rate of increase of flow or a small flow peak before the heavy runoff passes tends to decrease the magnitude of the quality change from what might otherwise occur. A sudden, sharp rise from the base flow did not occur during the six-week period the monitor was located at this station.

Storm Runoff from the Upper Wilson Creek Basin - During periods of rain, runoff into Jordan Creek from the downtown area is rapid, due to fairly steep gradients and very high proportions of paved and roof areas. The quality of this runoff is quite poor; and the longer the period of time since the preceding flushing rain, the poorer the quality of the runoff. The reasons for the poor quality of urban

runoff are discussed in a report by the American Public Works Association (2). The pollutants of urban storm runoff include street refuse (dust, dirt, litter, oil, disintegrated asphalt, animal droppings, etc.); stagnant and septic water from storm sewer catch basins, ditches, and other depressions; and chemicals from a host of sources.

The very poor quality of urban runoff has been investigated by a number of researchers. In a 1950 report (14), Palmer presents data on the quality of a series of water samples taken in a storm water catch basin in the business district of Detroit following a rain-storm in March. The BOD of the first sample was 234 mg/l and was 96 mg/l 2 1/2 hours later. Total solids content ranged up to 914 mg/l. In another 1950 report (1) in a foreign journal, Akerlindh reports a BOD of from 100 to 200 mg/l in stormwater flow. Wilkerson (23) in a 1954 report, found BOD values up to 100 mg/l and suspended solids levels up to 2,045 mg/l. Riis-Carstensen (15) in 1955 found the organic strength of storm runoff to be comparable to that of raw sewage. A Russian author (17) in a 1956 report found storm runoff in Moscow to have a BOD ranging from 186 to 286 mg/l, with suspended solids ranging from 1,000 to 3,500 mg/l. One sample from the streets of Leningrad had a suspended solids content of over 14,500 mg/l. Weibel, et al. (20), in a project at Cincinnati found no pronounced seasonal variation in the strength of urban runoff. Although the variation in concentration among the many samples was great, BOD had a maximum of 84 mg/l, COD maximum was 610 mg/l, and suspended solids maximum was 1,200 mg/l. Booth, et. al. (3), found storm

sewer flow in Toronto to have BOD's up to 260 mg/l and suspended solids up to 930 mg/l. Burm, et al. (4), tested an Ann Arbor, Michigan, storm sewer and found BOD's up to 62 mg/l and suspended solids up to 11,900 mg/l.

During rainy periods in Springfield, this poor quality runoff rushes into Jordan Creek and, taking algal mats and sediment into suspension as the rate of flow rapidly increases, moves downstream in slug-flow fashion.

Project personnel were able to observe this phenomenon firsthand on one occasion. On July 21, 1968, at about 4:15 p.m., Jordan Creek at Fort Street at the lower end of the railroad depot yards was visited. A brief, but intense, convectional-type thunderstorm centered over the downtown area was just ending. Although no rain occurred at the airport weather bureau station, the downtown streets had received a good flushing, as evidenced by curb-deep water downtown.

Whereas earlier in the day the stream at this point had been clear but choked with algal mats and flowing about 5 cfs, it was visually estimated to be at the rate of 75 cfs following the rainstorm. Its color was black even when observed in a small glass container. It smelled strongly of oil, and the consistency of the stream approached that of a slurry. Field tests were run on the water at that time, and additional samples were sent to the laboratory for analysis. Results of the field tests and laboratory analyses are as follows:

DO = 0.6 mg/l	PO ₄ -P = 0.39 mg/l
Temperature = 88°F	NO ₃ -N = 1.0 mg/l
pH = 3.9	NO ₂ -N = <0.005 mg/l
Conductivity = 290 umhos/cm	NH ₃ -N = 0.43 mg/l
BOD = 140 mg/l	Suspended Solids = 383 mg/l
COD = 408 mg/l	Oil and Grease = 31.9 mg/l

Examination of the above data reveals the very poor quality of the stream under storm runoff conditions.

The leading edge of this particular storm runoff was followed downstream and was observed at several downstream stations as it passed by. However, due to the limited extent and duration of the rainfall and consequently to the relatively small total volume of runoff, extreme effects did not occur at downstream stations. The further downstream the leading edge progressed, the flatter the shape of the hydrograph became. It is reasonable to assume that an intense 2- or 3-inch storm over a wider area would move a slug of poor quality water on the leading edge of the runoff all the way down Wilson Creek and, under extreme conditions, into the James River.

During periods of heavy runoff in the North Wilson Creek basin when stream residence time is much shorter than during low flow conditions and the opportunity for natural stream purification is lessened, it is a sound hypothesis that large volumes of poor quality water flow down North Wilson Creek into Wilson Creek, possible complicating already severe quality problems in that stream from runoff in the downtown area.

Sewage Treatment Plant Bypasses - As previously discussed, bypasses of the sewage treatment plant are necessary during periods of heavy rainfall. Such bypasses have been implicated in previous fish kills as the cause of the kills.

The timing of sewage bypasses with respect to rises in streamflow at the plant is an important consideration. City of Springfield personnel indicate that this is a variable relationship. On some occasions, bypass may begin about 30 minutes before the stream rises; but on other occasions, the two events occur simultaneously. During the heavy rains of July 30, 1968, bypassing commenced at 2:30 p.m. and reached a peak rate of 40 cfs at 3:00 p.m. Streamflow at the gage immediately below the plant began rapidly increasing from a rate of 20 cfs at about 2:15 p.m., had reached 200 cfs by about 3:00 p.m., and peaked at 990 cfs at 5:00 p.m.

On this particular occasion, the monitor at the north edge of the national park recorded a slug of low DO water which reached a low of 0.4 mg/l. These readings were verified at the site by Winkler DO tests. Earlier, DO had been measured at zero¹ in Wilson Creek at Rader Bridge. An attempt had been made to run a series of DO tests above the sewage plant in Wilson Creek; but a critical time period of 1 hour and 20 minutes was permitted to elapse between samples, during which time the leading edge of runoff passed by and any slug of low DO water which might have passed by was not recorded.

¹ Due to the nature of the modified Winkler method used to measure dissolved oxygen, and to the various interferences with the test, it is not technically possible to measure DO at zero, even though no DO was indicated by the test. Technically, all DO results listed as zero in this report could have been as high as 0.1 mg/l.

A series of DO tests were run on the plant bypass on one occasion in September, 1968. Beginning with the first bypass, up to a rate of 24 MGD over a two-hour-and-fifteen-minute period, the concentration of DO ranged from 2.6 mg/l to 3.8 mg/l.

The bypasses from the sewage treatment plant undoubtedly contribute to the poor quality water moving downstream. However, considering the volume of the bypasses in comparison with the volume of the storm runoff, the bypasses are considered to be of secondary importance. The bypasses of sewage alone are not of sufficient volume to cause a slug of low DO water in Wilson Creek of the magnitude measured by the monitor at the north edge of the national park. To illustrate, on July 30, 1968, the monitor recorded a slug of low DO water on the leading edge of storm runoff. During the period of time (about 15 minutes) when the DO was less than 0.5 mg/l, flow at the monitor went up from 350 cfs to 460 cfs. The peak rate of bypass was about 40 cfs. To put it another way, 292,000 cubic feet of water passed the monitor with less than 0.5 mg/l DO. The peak bypass during the same amount of time discharged only about 29,000 cubic feet of water into the stream.

Scour of Sludge Deposits - As previously discussed, rather extensive sludge deposits exist in Wilson Creek below the sewage treatment plant. When sudden flow increases occur, much turbulence is created which tends to stir up and take into suspension bottom sediments, algal masses, and sludge deposits. Many of these materials, particularly the sludge deposits, have a high affinity for oxygen. Thus, slugs

of low DO water coming from the downtown area or from the sewage treatment plant tend to be sustained in a poor condition, or further deteriorated, when under normal conditions reaeration would be occurring. This condition is considered to be highly significant to the problem under consideration.

ACKNOWLEDGMENT OF COOPERATING AGENCIES AND INDIVIDUALS

The support and assistance provided during this study by the following agencies and individuals is gratefully acknowledged. The successful completion of the project would have been considerably more difficult, if not impossible, without the outstanding spirit of help and cooperation demonstrated by these people.

City of Springfield, Missouri

V. W. Whitfield, Director of Public Works and City Engineer

Paul T. Hickman, Superintendent of Sanitary Services

Larry Kellogg, Engineering Technician III

James L. Aleshire, Superintendent of Sewage Treatment

Harry Criswell, Sanitary Chemist

Thomas Crance, Engineering Technician II

Charles Griffin, Equipment Operator

Robert Boblander, Laboratory Technician

Ronald Martin, Laboratory Technician

Missouri Water Pollution Board

Jack K. Smith, Executive Secretary

Ed Lightfoot, Chief Engineer

John F. Schondelmeyer, Chief of Industrial
Waste and Stream Surveys

Bill Sankpill, Stream Surveys Coordinator

Missouri Geological Survey

William C. Hayes, State Geologist and Director

James H. Williams, Chief of Engineering Geology

Jerry D. Vineyard, Chief of Publications
and Information

Larry D. Fellows, Chief of Stratigraphy

Edwin E. Lutzen, Engineering Geologist

Thomas J. Dean, Engineering Geologist

Missouri Conservation Commission

James R. Whitley, Water Quality Investigations

U. S. Geological Survey, Rolla, Missouri

Anthony Homyk, District Chief, Water Resources
Division and Staff

National Park Service

David L. Hieb, Superintendent, Wilson's Creek
Battlefield National Park

Charles T. Meier, Management Assistant, Wilson's
Creek Battlefield National Park

U. S. Weather Bureau

Ray Nelson, Station Manager, Springfield,
Missouri

BIBLIOGRAPHY

1. Akerlindh, Gunnar, "The Quality of Storm Water Flows," *Satryek ur Nordisk Hygienisk Tidskreff*, Vol. 31, No. 1, 1950.
2. American Public Works Association, *Water Pollution Aspects of Urban Runoff*, Contract No. WA 66-23, Water Pollution Control Research Report WP-20-15, Federal Water Pollution Control Administration, Jan. 1969, pp. 272.
3. Booth, F. T., Vardin, N., and Ball, G. L., "Toronto Confronts Outdated Sewers," *Journal of the Water Pollution Control Federation*, Vol. 39, No. 9, Sept. 1967.
4. Burm, R. J., Krawczyk, D. F., and Harlow, G. L., "Chemical and Physical Comparison of Combined and Separate Sewer Discharges," *Ibid.*, Vol. 40, No. 1, Jan. 1968.
5. Consoer, Townsend, and Associates, Consulting Engineers, "Report to the City of Springfield on Condition and Operation of the Sanitary Sewerage System," Chicago, Nov. 1967.
6. Harvey, E. J., and Skelton, John, "Hydrologic Study of a Waste-Disposal Problem in a Karst Area at Springfield, Missouri," U. S. Geological Survey Professional Paper 600-C, Rolla, Mo., 1968, pp. C217-C220.
7. Lagler, K. F., *Freshwater Fishery Biology*, Brown, Dubuque, 1956, pp. 421.
8. Mayor's Water Resources Committee, City of Springfield, Mo., "Pollution Alleviation of Wilson's Creek by Flow Augmentation Through Wilson's Creek Battlefield National Park," Dec. 1967.
9. Missouri Conservation Commission, Missouri Division of Health, and U. S. Public Health Service, "Report of Field Investigation of Wilson Creek Near Springfield, Missouri, With Reference to Conditions Promoting Fish Kill in the James River," 1954.
10. Missouri Conservation Commission, Missouri Water Pollution Board, and U. S. Public Health Service, "A Study of Pollution Effects Upon Water Quality, Life, and Stream Conditions in Wilson Creek and the James River, Greene and Christian Counties, Missouri," Sept. 1960.
11. Missouri Water Pollution Board, "A Water Quality Study of Wilson Creek and James River Below Springfield, Greene County, Missouri," Sept. 1966.

12. Missouri Water Pollution Board, "Statement by Missouri Water Pollution Board Concerning the Fish Kill in the James River on July 16, 1966."
13. Missouri Water Pollution Board, "Water Quality Standards, White, North Fork, Spring, Eleven Point, Current, and Black Rivers and Tributaries," June 1968.
14. Palmer, Clyde L., "The Pollutational Effects of Storm-Water Overflows from Combined Sewers," *Journal of the Sewage and Industrial Wastes Association*, Vol. 22, No. 2, Feb. 1950.
15. Riis-Carstensen, Erik, "Improving the Efficiency of Existing Interceptors," *Ibid.*, Vol. 27, No. 10, Oct. 1955.
16. Rounsefell, G. A., and Everhart, W. H., *Fishery Science, Its Methods and Applications*, Wiley, 1953, pp. 444.
17. Shigorin, G. G., "The Problem of City Surface Runoff Water," *Vodosnabzhenie i Sanitarnaya Teknika*, Vol. 2, No. 19, 1956.
18. Summerfelt, Robert C., and Lewis, William M., "Repulsion of Green Sunfish by Certain Chemicals," *Journal of the Water Pollution Control Federation*, Vol. 39, No. 12, Dec. 1967.
19. U. S. Army Corps of Engineers, "Flood Plain Information, Wilson Creek and Tributaries, Springfield, Missouri," Part I, Little Rock District, Nov. 1968.
20. Weibel, S. R., Anderson, R. J., and Woodward, R. L., "Urban Land Runoff as a Factor in Stream Pollution," *Journal of the Water Pollution Control Federation*, Vol. 36, No. 7, July 1964.
21. Whitley, James R., "James River Fish Kill," Missouri Department of Conservation, July 15, 1966.
22. White River Basin Coordinating Committee, "Comprehensive Basin Study, White River Basin, Arkansas and Missouri," June 1968.
23. Wilkerson, R., "The Quality of Rainfall Run-Off Water from a Housing Estate," *Journal of the Institute of Public Health Engineers*, London, 1954.



EXHIBIT A

The Department of Public Health and Welfare of Missouri
WATER POLLUTION BOARD
112 West High, P.O. Box 194
Area Code 314
Telephone 433-1484
Jefferson City, Missouri 65101

J. MARSHALL THOMPSON, Chairman
De Soto
A. PERRY PHILIPS, Vice Chairman
Columbia
W. C. HEWITT
Shelbyville
HARRY H. HILLIKER
St. Louis
RAYMOND KREBS
Springfield
JOE M. ROBERTS
Columbia
JACK K. SMITH
EXECUTIVE SECRETARY

ALL COMMUNICATIONS TO
WATER POLLUTION BOARD

5.3 Springfield

October 4, 1966

Mr. Jerome H. Svore
Regional Program Director
Federal Water Pollution Control
Administration
1114 Commerce Street
Dallas, Texas 75202

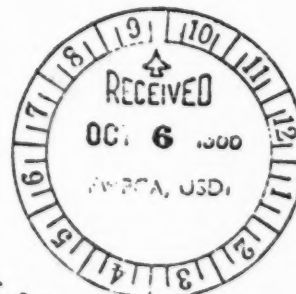
We request the assistance of the Federal Water Pollution Laboratory
Ada, Oklahoma in the study of an unusual pollution problem,
Springfield, Missouri. The pollution problem is believed to be
related to surface runoff as well as treated sanitary and industrial
waste tributary to Wilson Creek. It is our understanding the
Laboratory at Ada serves the Arkansas-White-Red River Basins.
Wilson Creek is a tributary to James River which flows into the
White River.

Your favorable consideration is requested.

Jack K. Smith
Executive Secretary
Missouri Water Pollution Board

JKS/ih

61



OCT 07 1966

